January 2016

An Economic Assessment of Household Unwanted Medicine Disposal Programs

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Graduate School Form
30 Updated 12/26/2015

PURDUE UNIVERSITY
GRADUATE SCHOOL
Thesis/Dissertation Acceptance

This is to certify that the thesis/dissertation prepared

By Sofia Katherina Vielma Delano

Entitled
AN ECONOMIC ASSESSMENT OF HOUSEHOLD UNWANTED MEDICINE DISPOSAL PROGRAMS

For the degree of Master of Science

Is approved by the final examining committee:

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AN ECONOMIC ASSESSMENT OF HOUSEHOLD UNWANTED MEDICINE DISPOSAL PROGRAMS

A Thesis

Submitted to the Faculty

of

Purdue University

by

Sofia Katherina Vielma Delano

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science

August 2016

Purdue University

West Lafayette, Indiana

To my family for their unconditional support and love.

ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Kwamena K. Quagrainie, for his constant guidance throughout the whole process. I also want to acknowledge my committee members, Dr. Wallace E. Tyner and Dr. Juan Pablo Sesmero, for their valuable input and suggestions for a successful completion of this thesis. Special thanks to the members of the Illinois-Indiana Sea Grant, Laura Kammin, Lisa Merrifield and Caitlin McCoy, for sharing their expertise on the topic and actively participating in the creation of the survey used for this study.

I am grateful to Illinois-Indiana Sea Grant for their funding support to complete this project. Likewise, I also wish to extend my appreciation to Jim and Neta Hicks for providing the financial support for the primary data collection. Lastly, I would like to thank my family and friends for their endless support throughout my graduate studies.

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ABSTRACT

Vielma Delano, Sofia K. M.S., Purdue University, August 2016. An Economic Assessment of Household Unwanted Medicine Disposal Programs. Major Professor: Dr. Kwamena K. Quagrainie.

There has been increasing concern about the environmental impact of pharmaceutical accumulations in surface and groundwater over the last two decades due to their improper disposal. Improper storage of these pharmaceuticals at home also poses a public health concern given its association with drug abuse and accidental poisoning. Several states in the U.S., including those bordering the Great Lakes, have implemented medicine take-back programs to help mitigate problems associated with unused and unwanted pharmaceuticals kept in households. Although positive benefits for society and the environment have been reported for these programs, the perceived monetary value has not been estimated. This thesis assessed the determinants of household participation in a medicine take-back program and estimated the value of a pharmaceutical collection program through a contingent valuation procedure.

An ordered logit model was estimated to assess the factors that can influence participation in a medicine take-back program. A double hurdle model was then used to estimate the mean willingness to pay (WTP) per prescription as well as per visit by current users of the program and potential users in the Great Lakes region.

The dataset used for the study consisted of a sample of 2,031 respondents from a survey that solicited information about unwanted and unused medicine disposal practices and willingness to participate in a medicine take-back program. The survey was administered online in the summer of 2015 to residents of Illinois, Indiana, Michigan, Minnesota, Ohio and Wisconsin.

The results suggest that young adults with an annual household income above the national median of $51,759 dollars and environmentally conscious individuals are more likely to participate in medicine take-back programs. Regarding participation, 60% of respondents are willing to participate in a collection program, while 40% are willing to pay to participate in a collection program. The unconditional mean WTP is $0.53 per prescription and $1.03 per visit, while the mean willingness to pay for those with a positive willingness to pay is $1.03 per prescription and $2.33 per visit. The total annual value for such programs in the Great Lakes region is estimated to be between $20.75 and $41.30 million under the WTP per prescription estimations, and $19.70 - $39.25 using the WTP per visit estimations. This information helps to better inform program providers, researchers, policymakers, advocates and other interested parties on the value of these collection programs.

CHAPTER 1. INTRODUCTION

This chapter introduces the research project conducted on valuing unwanted medicine take-back programs in the Great Lakes region. It provides a general overview motivating the study, followed by the problem statement, and then the general objectives. Finally, the hypothesis statements are presented.

1.1 Motivation

Pharmaceuticals are used to treat illnesses and diseases in both humans and animals. In the U.S., prescription[1] medicines play a very important role in the health care system. From 2009-2012, 48.7% of the population used at least one prescription drug within a 30-day period, while 21.8% had used three or more over the same period (NCHS, 2014). The increasing consumption of prescription medicines presents health, safety and environmental challenges associated with improper storage and disposal of unused and unwanted pharmaceuticals.

Studies have identified pharmaceutical chemicals in rivers, streams and groundwater in 71 countries across the world (IWW, 2014), and across the U.S. (Benotti, et al., 2009, Kolpin, et al., 2002). Pharmaceutical chemicals may also degrade into constituent compounds that persist in the environment.

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[1] In the following thesis, "prescription" will refer to both prescription and over-the-counter medications.

Improper disposal of medicines could result in higher concentrations of active pharmaceutical ingredients (APIs) in effluents. Households commonly dispose unwanted or expired drugs by pouring them down the sink or flushing them down the toilet, eventually entering the wastewater stream. Municipal sewage treatment plants are not equipped to degrade substances from pharmaceutical products, leading to the eventual presence of pharmaceuticals in waterways. The introduction and accumulation of pharmaceutical compounds in the environment is a growing issue, with latent implications for human health and ecosystems that are still not clearly understood. The Environmental Protection Agency (EPA) is working with the National Academy of Sciences to advice on the potential risk to human health from low residues of pharmaceuticals in drinking water. The Great Lakes, which provide drinking water, recreation, transportation, and industry to more than 40 million people in the North Central region are no exception to the risks of such accumulations (Blair, et al., 2013). In addition, the Great Lakes are also home to diverse and unique basin-wide ecosystems.

Pharmaceutical accumulation and unsafe storage in households can also pose a public safety hazard. Medicines are one of the most common poison exposure in the country (Mowry, et al., 2015), increasing the risk of accidental poisoning of children and pets. Prescription drug abuse and its potential health consequences are also a public health problem. According to the National Center for Health Statistics (NCHS), drug overdose death rates have increased five-fold since 1980, becoming the leading cause of accidental deaths in 29 states and Washington D.C. (NCHS, 2014). The estimated cost to the nation include lost productivity, medical costs and criminal justice costs, which amounts to $53.4 billion a year (NCHS, 2014).

Several states and counties across the Unites States have implemented medicine take-back schemes to mitigate the problems associated with unused and unwanted medications. Medicine take-back programs provide secure collection points and environmentally sound destruction of unwanted medicines to protect public health and the environment. The National Community of Pharmacists Association (NCPA) estimate that over 20,000 pounds of unused and/or unwanted medications have been collected at 1,600 participating pharmacies that have collection centers across the country (NCPA, 2016). The "Yellow Jug Old Drugs," program operated by the Great Lakes Clean Water Organization, is another program in Michigan, Wisconsin, Illinois, Indiana and it's expanding to Ohio. Jugs are located in pharmacies where users can drop their unused medications for free. In Wisconsin, there are about 80 permanent collection points at police stations throughout the state, along with one-day collection events. Minnesota has created medicine collection events called "Medicine Cabinet Clean-Out Days" through the Western Lake Superior Sanitation Department. The Illinois-Indiana Sea Grant (IISG) has contributed to the implementation of take-back activities around the Great Lakes, with concentration in Indiana and Illinois and a few activities in Michigan and Wisconsin. The program started in 2008 and included both single day programs and/or permanent locations. There are currently 39 programs operating in the Great Lakes region in addition to a national program Prescription Pill Drug Disposal Program (P_2D_2) in 54 counties in Illinois.

An important component of the take-back programs is to communicate the environmental impacts of pharmaceutical waste to consumers as well as to increase consumer awareness of the problem. Increased consumer awareness can reduce the risks of accidental poisoning and drive behavioral change towards better disposal practices.

Several studies have provided useful information regarding disposal practices, however the results have very specific regional or local applications. A study in Santa Barbara county in California found that consumers are willing to pay a $1.53 surcharge per prescription to support the establishment of a pharmaceutical disposal program (Kotchen, et al., 2009). The study also reported that willingness to pay varied with socioeconomic characteristic. Additional data is needed to better understand the benefits of these programs. This study analyzes household participation and willingness to pay for a pharmaceuticals disposal program in the Great Lakes region.

1.2 Problem Statement

A number of unwanted and unused medicine collection programs have been established throughout the Great Lakes region. These programs provide economic benefits to society by properly disposing unwanted household pharmaceuticals, reducing environmental pollution in water sources, and preventing adverse effects to organisms in the different ecosystems. Additionally, economic benefits arise from averting public health issues related to accidental poisoning and prescription medication abuse. There is no direct relationship between these positive impacts and the corresponding monetary value since these programs are a public good. Available literature suggests that it is very difficult to establish a correlation between the medicines collected and the reduction in pollution in each location given limited market economic data. Thus, to estimate the value of disposal programs established in the Great Lakes Region, a non-market valuation model needs to be employed. This research adopted multiple approaches to estimate the annual benefits of collection programs.

1.3 Overall Objectives

The overall objective of this research is to value medicine take-back programs in the Great Lakes region to better inform program providers, researchers, policymakers, advocates and other interested parties. The specific objectives are to:

1. Analyze the individual willingness to participate in a medicine take-back program.
2. Estimate the value of medicine take-back programs in the Great Lakes region using willingness to pay for such programs.

1.4 General Hypothesis Statements

The hypotheses for the respective objectives are:

1. An individual that has had unwanted pharmaceuticals in their home over the past 12 months and has a higher environmental awareness is likely to participate in a medicine take-back program.
2. An individual that has had unwanted pharmaceuticals in their home over the past 12 months and has a higher environmental awareness is willing to pay for a medicine take-back program.

1.5 List of References

Benotti, M.J., Trenholm, R.A., Vanderford, B.J., Holady, J.C., Stanford, B.D. and Snyder, S.A. 2009. "Pharmaceuticals and Endocrine Disrupting Compounds in U.S. Drinking Water." *Environ. Sci. Technol.* 43:597-603.

Blair, B.D., Crago, J.P., Hedman, C.J. and Klaper, R.D. 2013. "Pharmaceuticals and personal care products found in the Great Lakes above concentrations of environmental concern." *Chemosphere* 93:2116-2123.

Kolpin, D.W., Furlong, E.T, Meyer, M.T, Thurman, E.M., Zaugg, S.D., Barber, L.B and Buxton, H.T. 2002. "Pharmaceuticals, hormones, and other organic wastewater contaminants in US streams, 1999-2000: A national reconnaissance." *Environmental science & technology* 36:1202-1211.

Kotchen, M., Kallaos, J., Wheeler, K., Wong, C. and Zahller, M. 2009. "Pharmaceuticals in wastewater: Behavior, preferences, and willingness to pay for a disposal program." *Journal of Environmental Management* 90:1476-1482.

Mowry, J.B., Spyker, D.A, Brooks, D.E, McMillan, N., and Schauben, J.L. 2015. "2014 Annual Report of the American Association of Poison Control Centers' National Poison Data System (NPDS): 32nd Annual Report." *Clinical toxicology* 53:962-1147.

National Community Pharmist Association (NCPA). 2016 "Dispose My Meds." Accessed Online 03/20/2016. Avaiable In: http://www.ncpanet.org/solutions/dispose-my-meds

National Center for Health Statistics (NCHS). 2014 "Health, Unites States, 2013: With Special Feature on Prescription Drugs." In. Hyatsville, MD, U.S. Department of Health and Human Sciences.

Rheinisch-Westfaelisches Institut für Wasser (IWW). *"Pharmaceuticals in the environment: Occurence, effects, and options for action. ."* In. Mulheim, Germany, Gernab Federak Environmental Agency (UBA). Available online: https://www.pharmaceuticals-in-the-environment.org/

CHAPTER 2. BACKGROUND INFORMATION

This chapter provides an overview of pharmaceutical use and related environmental and public issues. Some of the studies regarding the presence of medications in the environment are discussed. The associated risks to both humans and wildlife are also highlighted. Finally, some of the policy recommendations to reduce the impact of unwanted and unused medications are mentioned. Special focus is centered on take-back programs implemented at the national and international level.

2.1 Trends of Pharmaceutical Consumption

Pharmaceuticals, also referred to as medicines or drugs[2] have been widely used throughout history. Worldwide, it is estimated that about 4,000 different active pharmaceutical ingredients (APIs) are administered with an estimated annual worldwide consumption of 100,000 tones (IWW, 2014). Although pharmaceuticals are treated as group of substances, they do not share any chemical, physical, structural or biological factors. In fact, some of these compounds have other uses besides medicines (e.g. nitroglycerine for vasodilation and dynamite). The only characteristic that brings this varied group of chemical compounds together is their use. This means that any biologically active substance has the potential to be a drug. Extensive research in pharmaceutical

[2] Drugs can also refer to illegal substances. In the following paper, any reference to 'drugs' will not consider this connotation.

companies focuses on selecting the substances that produce the desired effect in animals and/or humans, and with few or no adverse effects. Thus, from a risk-management approach, pharmaceuticals go through a very specific assessment to ensure overall human health and wellbeing. However, from an environmental risk assessment perspective, they are no different from other chemicals. In general, they do not pose any more risks than other biologically active components that have resulted from advances in analytical science. However, unlike other chemical components, they are not regulated by an international agreement or arrangement for their potential adverse effects. It is important to bear in mind that because of their increasing use and potential benefits to society, the risk/benefit calculations may differ significantly from other substances (Hester and Harrison, 2015).

The most consumed prescription drugs are anti-hypertensives and analgesics, followed by psychoactive products, anti-cholesterol agents, diabetes drugs and antibiotics (NCHS, 2014). According to the World Health Organization (WHO), the U.S. is the leader in total pharmaceutical expenditure and consumption, accounting for 32% of the world spending and 55% of the total consumption (WHO, 2011). From 2010-2011, the estimated U.S. national expenditure on overall prescriptions was $773 per capita. Consumption is projected to continue growing for the upcoming years as a result of new drugs, expanding population, aging population, and expiration of patents that result in more accessible generic medications (HCCI, 2014). Pharmaceuticals also play an important role in the U.S. national health care system, accounting for approximately 11% of overall health care expenditures in 2013. From 2009-2012, 48.7% of the population used at least one prescription drug within a 30-day period, while 21.8% had used three or more. Women, older adults and white persons are more likely to consume at least one prescription a day (NCHS, 2014). The increasing consumption of prescription medicines presents challenges associated with the excretion of these pharmaceuticals and the disposal of unused medications into the environment.

2.2 Pharmaceuticals in the Environment

Drug residues have been increasingly found in the environment including rivers, lakes, groundwater, and in lower levels in drinking water, soil, sediments, and manure (Benotti, et al., 2009, Blair, et al., 2013, Cargouet, et al., 2004, Hughes, et al., 2012, Kolpin, et al., 2002, Li, et al., 2010, Wu, et al., 2009). A 2014 global review of pharmaceutical persistence in the environment found that, of the 713 pharmaceuticals tested, 631 were above their detection limits in 71 different countries across the world (Hughes, et al., 2012, IWW, 2014). The global occurrence is illustrated in Figure 2.1. This is probably an incomplete picture of the problem, because there are no detection methods for all of the thousands of pharmaceuticals in use around the world, and the analytical methods are not standardized internationally, so detection limits may vary.

Some of the pharmaceutical substances that have been found include antibiotics, analgesics, lipid-lowering drugs, beta-blockers, x-ray contrast media, and synthetic estrogens. The average concentration detected in surface waters is 0.043 μg/L, with individual APIs ranging from traces to 1 μg/L concentrations (Hughes, et al., 2012). Higher concentrations may be found in highly populated areas or areas with high sewage effluents.

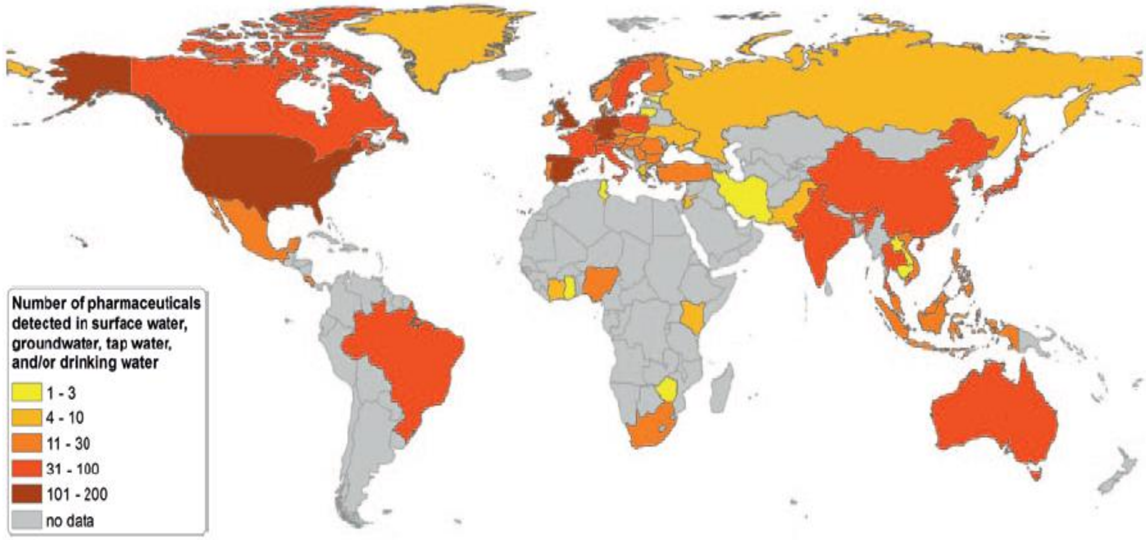

Figure 2.1: Global Occurrence of Pharmaceuticals Detected in Surface Water, Groundwater, Tap Water, and/or Drinking Water. (Source: IWW, 2014)

A number of drugs have been detected in the surface, shores, harbor, tributary rivers and sediments of the Great Lakes. Some examples of the 39 drugs found include metmorfin, caffeine, sulfamethoxazole, triclosan, carbamazepine, trimethoprim, naproxen, ibuprofen, gemfibrozil (Blair, et al., 2013, Li, et al., 2010, Metcalfe, et al., 2003, Wu, et al., 2009). Out of these 39 compounds, 14 were detected in Lake Michigan at high or medium risk levels near waste water treatment plant (WWTP) effluent areas. Some compounds dropped below the threshold levels to medium or low risk levels 2 miles away from the shore due to the dilution effect. Yet, this was not the case for all the chemicals (Blair, et al., 2013). As the biggest source of freshwater in North America, the potential environmental effects in Lake Michigan are concerning.

Figure 2.2: Main Emission Pathways of Human and Veterinary Pharmaceuticals Entering the Environment. (Source: IWW, 2014)

But how do pharmaceuticals end in our water supply and other ecosystems? The main sources and pathways through which medicines enter the environment are generally well identified. Figure 2.2 summarizes the main emissions pathways through which APIs can reach the different ecosystems. The left side of the diagram illustrates the main sources which include: the pharmaceuticals industry, hospitals and elderly care facilities, final consumers and animal husbandry and aquaculture.

The first pathway is through metabolic excretion from patients that end in the wastewater and hospital effluents. The APIs are excreted either as metabolized substances, or as unchanged active forms. A second pathway is from the industrial setting, where residues from the process end up either in the wastewater or waste. A third pathway is through excretion from animals which results as metabolites in manure and/or sludge.

Pharmaceuticals are also released into the soil when manure from animals treated with veterinary drugs is used as fertilizer. A fourth pathway is the improper disposal of unused medications through sinks and toilets that end in the sewage system. Medications are also improperly disposed through the garbage, where leakage in the landfills might result in APIs also entering the groundwater supply. Eventually, the APIs may accumulate in the soil or drain into the groundwater.

Wastewaters are treated in a WWTP before being discharged to a body of water. The problem with the compounds in medications is that conventional sewage treatment facilities, including activated sludge processes, are not equipped to degrade every type of medicinal substances. Studies suggest removal efficiencies at WWTP depend on the individual pharmaceutical and technology, ranging from 20% to 80% (Gibs, et al., 2007, Jelic, et al., 2011, Stackelberg, et al., 2007). Thus, a percentage of the medications that reach the municipal sewage are released into the surface and groundwater sources either in their original form or some kind of transformed chemical.

The biggest contribution with about 90% of the number of APIs in the environment comes from residues excreted from patients, while the discharges from the pharmaceutical industry account for only a small percentage (Hester and Harrison, 2015). The emissions from the first source are usually widespread but at extremely low levels. Studies that have evaluated the impact of discharges via excretion have found no evidence of any acute effects related with the trace levels of medication attributed to this pathway. Manufacturing discharges need to be regulated to avoid high concentrations in localized areas. In the U.S., monitoring and effluent standards result in a very small contribution to medicines in the water system from the pharmacy production. Although the extent at which unwanted medications are disposed improperly into the sewage system is not known (estimated between 5-10%), it is recognized that it has a significant impact on the load and concentration of the effluent (Hester and Harrison, 2015).

To estimate the real effect of unwanted medications improperly disposed into the environment, an estimation of the percentage of consumption from total sales for each individual pharmaceutical and the disposal source would be necessary. Thus, a great level of uncertainty exists in the estimations. Estimations from the European Union (E.U.) and the U.S. regarding unused prescriptions and disposal practices have been able to shed some light into this problem.

Unwanted medications in the E.U. have been estimated to represent 3 to 8% of total sales (Hester and Harrison, 2015). In the U.S., estimates by the Pharmaceutical Research and Manufacturers of America (PhRMA) of unused medications purchased by consumers are at least 3%, equivalent to 2.8 million pounds, and 7%, 1.5 million pounds, from patients in long-term facilities (PhRMA, 2011). Results from prescription adherence surveys suggest that these percentages might by underestimating the unused amounts of medicines in the country and amounts could actually represent 67% of total prescription medication purchased (Law, et al., 2015).

The most common reasons for accumulation of unwanted and unused medications in households are side effects to the medications, not adhering to the prescribed timeline of the medical prescription, forgetfulness, over-prescription by physicians, automatic refills, death of patient, and easy access to over the counter medications (Hester and Harrison, 2015, Law, et al., 2015). The most common unused medications in Europe are those related with cardiovascular diseases, asthma, nervous system and gastro-intestinal tract (Roig, 2010), while in the U.S., medicines related to chronic conditions such as hypertension, diabetes, cholesterol and heart disease, pain medication and mental health problems are the most commonly reported (Law, et al., 2015).

Medicine disposal behavior has been studied by several authors. In the U.S., the most common disposal method for leftover medications is the garbage, followed by flushing down the toiler or sink (Kotchen, et al., 2009, Kuspis and Krenzelok, 1996, Law, et al., 2015, Musson, et al., 2007). Only an estimate between 10-15% of people with medicines in their home dispose of them at a medicine collection center (Glassmeyer, et al., 2009, Thach, et al., 2013). Individuals that are more aware of the environmental risk of improperly disposing medicines are more likely to return their medications to a collection center (Blom, et al., 1996, Kotchen, et al., 2009, Persson, et al., 2009, Tong, et al., 2011).

Once in the environment, living organisms are exposed to pharmaceutical substances. Given that these metabolites may still contain APIs, they are potentially harmful to the species of each ecosystem. The vast majority of drugs have not been associated with a significant risk from chronic exposure to the concentrations in the environment, but some drugs may still have the potential to affect wildlife or people (Hester and Harrison, 2015). There is some evidence about the effects on metabolism regulation, reproduction and development, and signal transmission disruption between cells of some APIs, even at very low concentrations (Andersen, et al., 2003, Langston, et al., 2007, Swan, et al., 2006). Links between pharmaceutical exposure and harmful effects have been established in a limited number of different cases (Caldwell, et al., 2008, Hinck, et al., 2008, Vajda, et al., 2008). These are summarized in Figure 2.3.

				
Pharmaceutical	**Diclofenac**	**17α-Ethinylestradiol**	**Diclofenac**	**Sulfonamide**
Therapeutic group	Analgesics	Synthetic estrogen	Analgesics	Antibiotic
Non-target organism	Vulture (Gyps bengalensis)	Fathead minnow (Pimephales promelas)	Rainbow trout (Oncorhynchus mykiss)	Maize (Zea mays) Willow (Salix fragilis)
Effects	Population collapse due to renal failure	Population collapse due to feminization of male fish	Strong reactions of liver, kidney, and gills	Adverse effects on root growth. Death of maize at high conc.
Study type	Wildlife	Whole-lake experiment	Laboratory	Greenhouse
Reference	Oakes et al. 2004	Kidd et al. 2007	Triebskorn et al. 2007	Michelini et al. 2012

				
Pharmaceutical	**Fluoxetine**	**Oxazepam**	**Ivermectin**	**Enrofloxacin, Ciprofloxacin**
Therapeutic group	Antidepressant	Anxiolytics	Veterinary parasiticide	Antibiotics
Non-target organism	Leopard Frog (Rana pipiens)	European perch (Perca fluviatilis)	Dung fly and beetle	Cyanobacterium (Anabaena flosaquae) Duckweed (Lemna minor)
Effects	Delayed tadpole development	Altered behaviour and feeding rate	Mortality of eggs and larvae	Growth inhibition
Study type	Laboratory	Laboratory	Laboratory and field	Laboratory
Reference	Foster et al. 2010	Brodin et al. 2013	Liebig et al. 2010	Ebert et al. 2011

Figure 2.3: Selected Examples of Adverse Effects of Pharmaceuticals and Non-Target Organisms. (Source: IWW, 2014)

Ethinyl Estradiol (EE2), an active ingredient commonly used in contraceptive pills and patches and as a medicine for breast cancer, prostate cancer, hypogonadism and menopause has been detected since the late 1970's in surface waters all over the world (Andersen, et al., 2003, Caldwell, et al., 2008). EE2 is designed to mimic pretty closely its natural analogue, while being more resistant to degradation in the human body, resulting in a xeno-estrogen of high environmental concern. The median detection levels in lakes across the United States are 0.13 ng/L (Kolpin, et al., 2002). It has been shown that even at low concentrations it has negative effects for reproduction and development in wildlife given its persistence and high endocrine disruption potency (Andersen, et al., 2003, Cargouet, et al., 2004, De Mes, et al., 2005, Langston, et al., 2007, Xu, et al., 2010). A well-known case is the feminization of male fish. This effect is a consequence of exposure to estrogens in the environment that can either trigger the expression of the VTG gene or bind with receptors in the pituitary and/or hypothalamus, interfering with the natural feedback mechanism of the endocrine system. Female fish can also suffer reproduction disruptions that result in smaller eggs or inhibition of ovulation. The risk of these reproduction and development disorders is the sustainability of fish population and the adverse impacts this would have in other wildlife species.

Diclofenac is a non-steroid anti-inflammatory drug that was widely used for pain relief in cattle prior to their deaths in the Indian Sub-continent. From 1996 and 2007, millions of vultures would feast on the dead cattle carcasses, consuming the diclofenac residues (Swan, et al., 2006). These birds, and the Gyps species (*Gyps bengalensis*) in particular, have proven to be very sensitive to diclofenac, developing lethal gout in liver and tissue, and kidney failure even when consuming very low doses of the drug (Oaks, et al., 2004, Swan, et al., 2006). An estimate ranging from 10 to 40 million vultures died as a result of exposure and 3 different species are critically endangered in Asia (Green, et al., 2004). Veterinary diclofenac is now banned in India, Pakistan, and Nepal, yet this has not resulted in full recovery of the vulture populations (IWW, 2014).

Due to the low concentrations of APIs found in the environment and the limitation of reliable methods to monitor pharmaceutical residues in the environment, adverse effects in the different ecosystems can be very difficult to determine. Furthermore, most of the affected organisms that live in the water are rarely observed in a day to day basis. Thus, unless researchers are specifically assessing a species, any mild effect will most likely go unnoticed. Consequently, stakeholders are concerned about the potential effects pharmaceuticals may have on wildlife, particularly the long-term chronic effects that result from bioaccumulation.

2.2.1 Pharmaceuticals in Drinking Water

Pharmaceuticals have also been found in the drinking water supply. Unlike surface and groundwater, the concentrations found in human water supply is 100-fold below the minimum therapeutic dose of 0.05 μg/L (Jelić, et al., 2012, WHO, 2012). The presence and concentration of specific pharmaceuticals in drinking water varies from place to place, depending on the primary pathway and total influents, dilution, natural attenuation and the wastewater treatment technology employed. An analysis of 19 drinking water utilities in 2006 and 2007 in the U.S. found consistent traces of atenolol, carbamazepine, estrone, gemfibrozil, meprobamate, naproxen, phenytoin, sulfamethoxazole, and trimethoprim in source waters (Benotti, et al., 2009). Only meprobamate and phenytoin were detected in finished water distribution systems. Median concentrations of all these APIs were consistent with the world average concentrations, considerably below the therapeutic dose (WHO, 2012).

An important finding of a study of pharmaceuticals in U.S. drinking water was that the most prescribed pharmaceuticals were not detected in the drinking water supply, while the 3 most detected drugs in source water were not even in the top 200 prescribed pharmaceuticals (Benotti, et al., 2009). This discovery suggests prescription information is a poor proxy to medicine concentrations in water. For a more accurate measure, dosage, pharmacokinetics, wastewater treatment technology and efficiency and environmental fate need to be considered.

The World Health Organization suggests that due to this safety margin, it is very unlikely humans will suffer any consequence from the current trace exposure (WHO, 2012). Nevertheless, potential effects in the future as a result of chronic exposure to trace contaminants are a latent concern. The increase of water demand could potentially lead to greater incidence of indirect and direct water reuse, and this could result in an increased exposure to higher concentrations (Jones, et al., 2005).

Unfortunately, there is no information regarding the assessment of risks to human health from long term exposure to low concentrations of medicines in drinking water, or the possible combined effects from a mixture of APIs. There is a need to close the knowledge gap regarding long-term, low level exposure (Jelić, et al., 2012, WHO, 2012). Studies on the impact in more sensitive subpopulations such as children, pregnant women, immune compromised individuals, and allergic people are another area of opportunity.

Evidence suggests that implementing additional specialized and costly drinking water systems would not be efficient. No adverse effects to human health have been documented so far, thus the health benefits would be limited. Preventing or reducing initial concentration of pharmaceuticals in water sources should be sufficient to minimize the risk of exposure. Specific action may be considered for localized areas where higher APIs concentration has been detected and/or the influent discharge is significant and close to important water sources.

2.3 Public Health Issues

All prescription medications represent an incurred expense. In some cases, the economic investment may be considerable. Thus, disposing of these medications may represent money thrown away. Some consumers prefer to keep the medicines in their house in case it is ever needed again or to give away to someone else that might need them. Both of these behaviors represent other potential risks that arise with unused and unwanted drugs.

Pharmaceuticals are considered the most common poison exposure in the country (Mowry, et al., 2015). Accumulated medications in the house can increase the risk of accidental poisoning of children and pets. Children often like to explore their surroundings. If not properly stored, medicines around the home can be accidentally ingested. In 2003, 78,000 children under the age of five were treated for accidental poisoning of prescription medications in the U.S. (CPSC, 2005). According to a study from the Cincinnati Children's Hospital, 12% of the cases of children poisoning with both prescription and over-the-counter medications required admission to the hospital and 4% of the cases resulted in injuries. Accidental drug poisoning among children increased 22% from 2001 to 2008 with only 5% of the cases related to dosing errors and 95% attributable to unintentional consumption (Bond, et al., 2012).

Drug sharing with family and/or friends in the U.S. is illegal. Consumers might engage in this practice with the purpose of reducing the cost of prescription for someone else. The problem is that the purity of the medication cannot be assured. In cases where medications haven't actually been prescribed to the individual, drug sharing is equivalent to self-medication. The risk is the potential side effects as a reaction to other medications the person is taking and/or particular individual characteristics (e.g. allergies) (Glassmeyer, et al., 2009). Furthermore, sharing medications with family and friends can contribute directly to the abuse problem by providing an easy supply point.

The non-medical use of prescription drugs in the U.S. is a significant problem nationally, especially among adolescents. According to the National Institute on Drug Abuse, an estimated 52 million people have abused prescription drugs at least once, from which 6 million reported abusing them over the previous month (NCHS, 2014). Similarly, the Partnership Attitude Tracking Study found that 24% of teenagers had misused or abused prescriptions at least once, accounting for the third most prevalent drug behavior amongst this population group (Kids, 2014). Only marijuana and alcohol have a higher prevalence. In the last decade, abuse has increased dramatically. For example, the two most commonly abused substances, opioids hydrocodone and oxycodone, have increase by 170% and 450% respectively since 1994 (NIDA, 2005).

The main reason for abuse of prescription medications across all ages is the desire to experience the side effects (*i.e.* “getting high”). Among teenagers, another common reason is the misconception of enhancing brain activity to improve school performance (Kids, 2014). Most teenagers that abuse prescriptions usually obtain the drugs either through friends or relatives, or from their parent’s medicine cabinet.

According to the National Center for Health Statistics (NCHS), drug overdose death rates have increased five-fold since 1980, becoming the leading cause of accidental deaths in 29 states. In 2014, more than 1,700 young adults died from prescription drug overdoses, higher than from any other drug (NCHS, 2014). The estimated cost to the nation include lost productivity, medical costs and criminal justice costs, which amounts to $53.4 billion a year (NCHS, 2014).

2.4 Policy Recommendations

Pharmaceutical pollution is an emerging problem that needs to be addressed to protect ecosystems and public health. The Strategic Approach to International Chemicals Management (SAICM), a policy framework adopted by the International Conference on Chemicals Management (ICCM) commissioned by the United Nations Development Programme (UNDP), adopted environmentally persistent pharmaceutical pollutants as an emerging policy issue in their last meeting in September 2015. The resolution acknowledges that in order to prevent, reduce and manage this issue, a multi-sectoral, multi-stakeholder approach is needed. Coordination between intergovernmental organizations, national governments, pharmaceutical companies, health care professionals, veterinarians, waste water treatment plants, health insurance, academia and end user would be more successful in ensuring sustainable policies. Some of the risk mitigation proposals include monitoring campaigns, increasing environmental awareness, improving sanitation and sewage treatment plants, updating and implementing of environmental standards, and proper disposal of unwanted/expired pharmaceuticals.

In the U.S., 3 different agencies regulate the manufacturing, collection, discharge and disposal of medicines: the U.S. Environmental Protection Agency (EPA), the Federal Drug Administration (FDA) and the Drug Enforcement Agency (DEA). Some of the regulations enforced by these agencies to address environmental and public health issues related with pharmaceuticals are:

- Under the Federal Food, Drug and Cosmetics Act of 1980 (FFDCA), the FDA is responsible of requesting and evaluating an environmental impact assessment during the drug approval process. The National Environmental Protection Act (NEPA) requires this assessment from all federal agencies that will decide upon an action that may affect the human environment. The environmental assessment evaluates potential environmental impacts from pharmaceutical production. It should consider toxicity to organisms from the increased levels of APIs in the environment resulting from the process and disposal of the product. However, if the estimated concentration at the point of entry is below 1 part per billion, companies may qualify for a categorical exclusion.
- The EPA, through the Safe Drinking Water Act (SDWA), governs public water systems and establishes regulatory standards for over 100 chemical and microbial contaminants in drinking water. In addition, the EPA has a list, Contaminant Candidate List (CCL), which is continuously updated.
- The Clean Water Act (CWA), also regulated by the EPA, helps prevent disposal of pharmaceuticals from the industry to the public sewer system. However, even though it regulates the wastewater treatment plants through the National Pollutant Discharge Elimination System and could control the amount of pharmaceuticals discharged by the plants, it usually does not monitor these pollutants.
- The DEA, under the Drug Abuse Prevention and Control Act, regulates the disposal of pharmaceuticals. It does not regulate individual consumer disposal as long as it is the prescription holder that disposes them. Returning controlled

substances to pharmacies and distributors (except recall or dispensing errors) is prohibited.

These regulations have proven to be insufficient in addressing the emerging environmental problems. To properly inform policymakers on how to close the current gaps in regulation, further research needs to be done to better understand and determine the impact of pharmaceuticals in the environment.

Some of the concrete actions that could help mitigate the environmental and public health issues of medicines by stakeholder, are:

1) Pharmaceutical industries: Pharmaceutical research and development to produce drugs with non-persistent APIs after excretion and optimization of processes to reduce biologically active waste (IWW, 2014, PSI, 2012, NRDC, 2009).
2) Government agencies: Tighter regulation regarding environmental impacts through environmental assessments prior to granting approvals for production and evaluation of APIs in sewage systems. Revision of current regulations may also contribute to the reduction of medicines in the aquatic environment (PSI, 2012, NRDC, 2009).
3) WWTP: Improve removal in WWTP plants by using innovative processes. Accurate data of concentrations of pharmaceutical residues in these plants requires the development and standardization of advanced methods for monitoring pharmaceuticals in different environments (IWW, 2014, PSI, 2012).
4) Researchers: Close the knowledge gap regarding the environmental and health impact of persistent pharmaceuticals in ecosystems and drinking water. Some of the research areas in need are: i) Volume and type of medications excreted and

disposed; ii) Volume and magnitude of specific APIs in the environment; iii) Contribution of environmental pollution from each source (human excretion, industrial, animals and improper disposal); iv) types of persistent pharmaceuticals in the environment and potential effects in ecosystems and human health (IWW, 2014, PSI, 2012) .

5) Consumers: Disposal of unused and unwanted medications following best management practices (IWW, 2014, PSI, 2012, NRDC, 2009).
6) Health providers and pharmacies: Reduce unnecessary pharmaceutical use by decreasing over-prescription of healthcare providers, optimize pharmacy processes (e.g. auto-refills, prescription plans), limit pharmaceutical marketing campaigns, and awareness campaigns to reduce the overuse of antibiotics and over-the-counter medications. (PSI, 2012, NRDC, 2009).

From all the policy proposals, the most important among the general population is the proper disposal of medications. Improperly disposed medications are an easily preventable source of contamination (IWW, 2014). The establishment and promotion of take-back schemes for collection and disposal of unwanted and/or expired medications has increased worldwide. The objective of these programs is to reduce the number of pharmaceuticals that enter the environment by providing secure collection points and more environmentally friendly destruction. Besides the disposal service, most programs focus on increasing awareness of the risks of improper disposal. Another advantage of these programs is the information that could be collected to have a better understanding of why medications have accumulated. This information may be useful in the future to ensure a more efficient supply chain. Existing programs vary significantly. Collection schemes can be one-day events, permanent drop-off sites in pharmacies, hospital center or police departments, and mail-back programs.

In the European Union, take-back medicine schemes have been required by the medicinal legislation since 2004 through the Directive 2004/27/EC. Out of 27 Member States, 16 had recollection programs for unused and unwanted pharmaceuticals in 2013. More than half are operated by the pharmaceutical industry or in collaboration with the industry, and the remaining are paid by the local governments. The effectiveness of these programs is yet to be evaluated.

In Canada, pharmaceutical companies have implemented a very successful drug collection program in British Columbia since 1996. The British Columbia Medications Return Program allows consumers to return medications free of charge in approximately 95% of pharmacies in the province. In 2011, 152,216 pounds of medicines were collected. Some of the success factors have been the simple design and low cost of the program, outreach to pharmacy certification boards and support of participating pharmacies (BCMRP, 2014). Unlike the U.S., Canada does not have strict laws regulating custody of controlled substances, facilitating the creation and support of similar projects.

Numerous states and counties across the U.S. have established pharmaceutical take-back programs, including permanent drop-off sites, single day collection events, and mail-back programs. Clark County, Washington has had an unwanted medication take-back program since 2003 (Clark County, 2016). Residents can drop-off their medications at no charge at one of the 47 participating pharmacies. When pharmacies have filled the containers, they ship them to the county’s hazardous waste contractor for incineration with charge to the county. The solid waste managers of La Crosse County, Wisconsin developed a medicine disposal center for households. Residents from this county can drop-off all household medicines for free, while residents from other counties and small businesses (classified as very small quantity generators of hazardous waste) can participate and pay a small fee. Medicines are discarded into a 55-gallon drum of solvent where they dissolve. Once or twice a year, the containers are taken to incinerators. Estimated total annual costs range from $12,000-$15,000, which are covered by the solid waste department's regular operating budget (La Crosse County, 2016).

In the Great Lakes region, a number of examples of pharmaceutical collection programs include the Yellow Jug Old Drugs, operated by Great Lakes Clean Water Organization, available in Michigan, Wisconsin, Illinois, Indiana and expanding to Ohio. Jugs are located in pharmacies were users can drop their unused medications for free. In Wisconsin, there are around 80 permanent collection points in police stations throughout the state, along with one-day collection events (PSI, 2012). Minnesota has created medicine collection events called "Medicine Cabinet Clean-Out Days through the Western Lake Superior Sanitation Department. The Illinois-Indiana Sea Grant (IISG) has contributed to the implementation of take-back schemes around the Great Lakes, concentrating in Indiana and Illinois with a few in Michigan and Wisconsin. These 39 programs started operating in 2008 and included both single day programs and/or permanent locations. Additionally, in Illinois the national program Prescription Pill Drug Disposal Program (P^2D^2) is available in 54 counties. This program started as a research project from High School Students in Pontiac, Illinois (P2D2, 2016).

Despite the availability of take-back programs, a large percentage of the population does not have sufficient access to secure medicine disposal centers. Estimation by the

University of Wisconsin-Extension suggests only 2% of unused pharmaceuticals are collected through these programs (PSI, 2012). As the public becomes more aware about the risk of improperly disposing their medications, it is very likely the number of programs across the country will continue to grow.

One of the problems with the establishment of these programs is that the Federal Controlled Substance Act (CSA) did not allow the acceptance of controlled substances from end-users, unless it was a law enforcement officer. A recent amendment has expanded the options for the collection of controlled substances with the purpose of disposal (DEA, 2014). Yet, organizing and satisfying all legal requirements may impact the establishment of new collection programs.

The vast majority of these programs are free to the users. Thus, program providers incur costs associated with the program. Total annual costs vary significantly given the size and type of program and extent of advertising. Cost ranges may vary from hundreds of dollars to hundreds of thousands of dollars. Some of the costs may include: advertising, security cameras, secure metal drop boxes, collection supplies, consolidation costs at central collection site, warehousing, handling and transportation to disposal facilities, disposal costs, personnel wages, and rent.

For more programs to be established, and a continuous support to the existing ones, stakeholders (e.g. regulators, legislators, program providers, pharmaceutical industries, tax payers) must be convinced that the societal benefits from these programs are higher than the costs sustained.

2.5 List of References

Andersen, L., H. Holbech, Å. Gessbo, L. Norrgren and G.I. Petersen. 2003. "Effects of exposure to 17α-ethinylestradiol during early development on sexual differentiation and induction of vitellogenin in zebrafish (Danio rerio)." *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology* 134:365-374.

British Columbia Medications Return Program (BCMRP). 2014 *"Returning Unused and Expired Medications In British Columbia".* Available Online: http://www.healthsteward.ca/returns/british-columbia#

Benotti, M.J., Trenholm, R.A., Vanderford, B.J., Holady, J.C., Stanford, B.D. and Snyder, S.A. 2009. "Pharmaceuticals and Endocrine Disrupting Compounds in U.S. Drinking Water." *Environ. Sci. Technol.* 43:597-603.

Blair, B.D., Crago, J.P., Hedman, C.J. and Klaper, R.D. 2013. "Pharmaceuticals and personal care products found in the Great Lakes above concentrations of environmental concern." *Chemosphere* 93:2116-2123.

Blom, A., J. De Bruijn, and F. Van de Vaart. 1996. "How consumers deal with the remainders of unused prescription drugs." *Pharmaceutisch Weekblad* 131:102-107.

Bond, G.R., R.W. Woodward, and M. Ho. 2012. "The growing impact of pediatric pharmaceutical poisoning." *The Journal of pediatrics* 160:265-270. e261.

Caldwell, D.J., F. Mastrocco, T.H. Hutchinson, R. Länge, D. Heijerick, C. Janssen, P.D. Anderson and J.P. Sumpter. 2008. "Derivation of an aquatic predicted no-effect concentration for the synthetic hormone, 17α-ethinyl estradiol." *Environmental science & technology* 42:7046-7054.

Cargouet, M., D. Perdiz, A. Mouatassim-Souali, S. Tamisier-Karolak and Y. Levi. 2004. "Assessment of river contamination by estrogenic compounds in Paris area (France)." *Science of The Total Environment* 324:55-66.

Clark County, 2016. *Unwanted Medications.* Washington. Available Online: https://www.clark.wa.gov/environmental-services/unwanted-medications

Consumer Product Safety Commission (CPSC). 2005. *Poison Prevention Packaging - Consumer Product Safety Review, 2005.* Washington D.C.: NEISS Data Highlights. Available Online: https://www.cpsc.gov/en/media/documents/business--manufacturing/business-education/poison/poison-prevention-packaging-a-guide-for-healthcare-professionals/

De Mes, T., G. Zeeman, and G. Lettinga. 2005. "Occurrence and fate of estrone, 17β-estradiol and 17α-ethynylestradiol in STPs for domestic wastewater." *Reviews in Environmental Science and Bio/Technology* 4:275-311.

Drug Enforcement Administration (DEA). 2014. *Disposal of Controlled Substances; Final Rule*. Department of Justice. 79:1300,1301,1304. Available Online: www.deadiversion.usdoj.gov/fed_regs/rules/2014/2014-20926.pd

Gibs, J., P.E. Stackelberg, E.T. Furlong, M. Meyer, S.D. Zaugg and R.L. Lippincott 2007. "Persistence of pharmaceuticals and other organic compounds in chlorinated drinking water as a function of time." *Science of The Total Environment* 373:240-249.

Glassmeyer, S.T., E.K. Hinchey, S.E. Boehme, C.G. Daughton, I.S. Ruhoy, O. Conerly, R.L. Daniels, L. Lauer, M. McCarthy, T.G. Nettesheim, K. Sykes and V.G. Thompson 2009. "Disposal practices for unwanted residential medications in the United States." *Environment International* 35:566-572.

Green, R.E., I. Newton, S. Shultz, A.A. Cunningham, M. Gilbert, D.J. Pain and V. Prakash. 2004. "Diclofenac poisoning as a cause of vulture population declines across the Indian subcontinent." *Journal of applied ecology* 41:793-800.

Health Care Cost Institute (HCCI). 2014 "Spending on Prescriptions in 2011: Findings from HCCI's Health Care Cost and Utilization Report: 2011." In. Washington, D.C. Available Online: http://www.healthcostinstitute.org/files/HCCI_IB4_Prescriptions.pdf

Hester, R.E., and R.M. Harrison. 2015. *Pharmaceuticals in the Environment*: Volume 41: Royal Society of Chemistry.

Hinck, J.E., Blazer, V.S., Denslow, N.D., K.R., Echols, Gale, R.W., Wieser, C., May, T.W., Ellersieck, M., Coyle, J.J. and Tillitt, D.E. 2008. "Chemical contaminants, health indicators, and reproductive biomarker responses in fish from rivers in the Southeastern United States." *Sci Total Environ* 390:538-557.

Hughes, S.R., P. Kay, and L.E. Brown. 2012. "Global synthesis and critical evaluation of pharmaceutical data sets collected from river systems." *Environmental science & technology* 47:661-677.

Jelic, A., M. Gros, A. Ginebreda, R. Cespedes-Sánchez, F. Ventura, M. Petrovic and D. Barcelo. 2011. "Occurrence, partition and removal of pharmaceuticals in sewage water and sludge during wastewater treatment." *Water Research* 45:1165-1176.

Jelić, A., M. Petrović, and D. Barceló. 2012 "Pharmaceuticals in Drinking Water." In D. Barceló ed. *Emerging Organic Contaminants and Human Health*. Berlin, Heidelberg, Springer Berlin Heidelberg, pp. 47-70.

Jones, O.A., J.N. Lester, and N. Voulvoulis. 2005. "Pharmaceuticals: a threat to drinking water?" *Trends in Biotechnology* 23:163-167.

Kolpin, D.W., Furlong, E.T, Meyer, M.T, Thurman, E.M., Zaugg, S.D., Barber, L.B and Buxton, H.T. 2002. "Pharmaceuticals, hormones, and other organic wastewater contaminants in US streams, 1999-2000: A national reconnaissance." *Environmental science & technology* 36:1202-1211.

Kotchen, M., Kallaos, J., Wheeler, K., Wong, C. and Zahller, M. 2009. "Pharmaceuticals in wastewater: Behavior, preferences, and willingness to pay for a disposal program." *Journal of Environmental Management* 90:1476-1482.

Kuspis, D., and E. Krenzelok. 1996. "What happens to expired medications? A survey of community medication disposal." *Veterinary and human toxicology* 38:48-49.

La Crosse County, 2016. *Medication Drop-off*. Solid Waste Department, Wisconsin. Available Online: http://www.co.la-crosse.wi.us/solidwaste/

Langston, W., G. Burt, and B. Chesman. 2007. "Feminisation of male clams Scrobicularia plana from estuaries in Southwest UK and its induction by endocrine-disrupting chemicals." *Marine Ecology-Progress Series*- 333:173.

Law, A.V., P. Sakharkar, A. Zargarzadeh, B.W.B. Tai, K. Hess, M. Hata, R. Mireles, C. Ha and T.J. Park. 2015. "Taking stock of medication wastage: Unused medications in US households." *Research in Social and Administrative Pharmacy* 11:571-578.

Li, H., P.A. Helm, and C.D. Metcalfe. 2010. "Sampling in the Great Lakes for pharmaceuticals, personal care products, and endocrine-disrupting substances using the passive polar organic chemical integrative sampler." *Environmental Toxicology and Chemistry* 29:751-762.

Metcalfe, C.D., X.S. Miao, B.G. Koenig and J. Struger. 2003. "Distribution of acidic and neutral drugs in surface waters near sewage treatment plants in the lower Great Lakes, Canada." *Environmental Toxicology and Chemistry* 22:2881-2889.

Mowry, J.B., Spyker, D.A, Brooks, D.E, McMillan, N., and Schauben, J.L. 2015. "2014 Annual Report of the American Association of Poison Control Centers' National Poison Data System (NPDS): 32nd Annual Report." *Clinical toxicology* 53:962-1147.

Musson, S.E., T. Townsend, K. Seaburg and J. Mousa. 2007. "A continuous collection system for household pharmaceutical wastes: a pilot project." *Journal of the Air & Waste Management Association* 57:828-835.

National Center for Health Statistics (NCHS). 2014 "Health, Unites States, 2013: With Special Feature on Prescription Drugs." In. Hyatsville, MD, U.S. Department of Health and Human Sciences. Available Online:
http://www.cdc.gov/nchs/data/hus/hus13.pdf

National Institute on Drug Abuse (NIDA). 2005. *NIDA Community Drug Alert Bulletin*. National Institute of Health. Available Online:
http://archives.drugabuse.gov/PrescripAlert/

Natural Resources Defense Council (NRDC). 2009. *Dosed without Prescription: Preventing Pharmaceutical Contamination of Our Nation's Drinking Water.* Available Online: https://www.nrdc.org/sites/default/files/hea_10012001a.pdf

Oaks, J.L., M. Gilbert, M.Z. Virani, R.T. Watson, C.U. Meteyer, B.A. Rideout, H. Shivaprasad, S. Ahmed, M.J.I. Chaudhry and M. Arshad. 2004. "Diclofenac residues as the cause of vulture population decline in Pakistan." *Nature* 427:630-633.

Prescription Pill and Drug Disposal (P2D2). 2016 "About P2D2." Available online: https://p2d2program.wordpress.com/faq/disposal/

Partnership for Drug Free Kids (PfDFK). 2014 "2013 Partnership Attitude Tracking Study." Available online: http://www.drugfree.org/newsroom/pats-2013-full-report-key-findings

Persson, M., E. Sabelström, and B. Gunnarsson. 2009. "Handling of unused prescription drugs—knowledge, behaviour and attitude among Swedish people." *Environment International* 35:771-774.

Pharmaceutical Research and Manufacturers of America (PhRMA). 2011. "Improving Prescription Medicine Adherence is Key to Better Health Care." In. Washington, D.C., PhRMA. Available Online:
http://www.phrma.org/sites/default/files/pdf/PhRMA_Improving%20Medication%20Adherence_Issue%20Brief.pdf

Product Stewardship Institute (PSI). 2012. "Protecting our Health and the Environment: The Need for Sustainably Financed Drug Take-Back Programs." Available Online:
http://c.ymcdn.com/sites/www.productstewardship.us/resource/resmgr/Resources_-_PS-Products/Pharmaceuticals_White_Paper_.pdf

Rheinisch-Westfaelisches Institut für Wasser (IWW). *"Pharmaceuticals in the environment: Occurence, effects, and options for action. ."* In. Mulheim, Germany, Gernab Federak Environmental Agency (UBA). Available online: https://www.pharmaceuticals-in-the-environment.org/

Roig, B. 2010. "Pharmaceuticals in the environment: current knowledge and need assessment to reduce presence and impact." *Water Intelligence* Online 9:9781780401430.

Stackelberg, P.E., J. Gibs, E.T. Furlong, M.T. Meyer, S.D. Zaugg and R.L. Lippincott. 2007. "Efficiency of conventional drinking-water-treatment processes in removal of pharmaceuticals and other organic compounds." *Science of The Total Environment* 377:255-272.

Swan, G.E., R. Cuthbert, M. Quevedo, R.E. Green, D.J. Pain, P. Bartels, A.A. Cunningham, N. Duncan, A.A. Meharg and J.L. Oaks. 2006. "Toxicity of diclofenac to Gyps vultures." *Biology letters* 2:279-282.

Thach, A.V., C.M. Brown, and N. Pope. 2013. "Consumer perceptions about a community pharmacy-based medication take back program." Journal of Environmental Management 127:23-27.

Tong, A.Y., B.M. Peake, and R. Braund. 2011. "Disposal practices for unused medications around the world." *Environment International* 37:292-298.

Vajda, A.M., Barber, L.B, Gray, J.L., Lopez, E.M., Woodling, J.D. and Norris, D.O. 2008. "Reproductive Disruption in Fish Downstream from an Estrogenic Wastewater Effluent." *Environ. Sci. Technol*. 42:3407-3414.

World Health Organization (WHO). 2012. *"Pharmaceuticals in drinking-water."* Water Sanitation Health. Available Online. http://www.who.int/water_sanitation_health/emerging/info_sheet_pharmaceuticals/en

World Health Organization (WHO). 2011 Essential Medicines and Health Products. "*The World Medicines Situation Report*." Available Online: http://www.who.int/medicines/areas/policy/world_medicines_situation/en/

Wu, C., J.D. Witter, A.L. Spongberg and K.P. Czajkowski. 2009. "Occurrence of selected pharmaceuticals in an agricultural landscape, western Lake Erie basin." *Water Research* 43:3407-3416.

Xu, Q., S.-Y. Wu, M. Wang, X.-Y. Yin, Z.-Y. Wen, W.-N. Ge and Z.-Z. Gu. 2010. "Electrospun nylon6 nanofibrous membrane as SPE adsorbent for the enrichment and determination of three estrogens in environmental water samples." *Chromatographia* 71:487-492.

CHAPTER 3. ANAYSIS OF THE FACTORS THAT DETERMINE HOUSEHOLD PARTICIPATION IN A MEDICINE TAKE-BACK PROGRAM

3.1 Introduction

Over the last decade, pharmaceutical residues have been increasingly found in surface and groundwater in at least 71 countries around the world (Hughes, et al., 2012, IWW, 2014). In Lake Michigan, 631 chemicals out of 713 that were tested, were found above detection limits (Blair, et al., 2013). The pharmaceutical substances found include antibiotics, analgesics, lipid-lowering drugs, beta-blockers, x-ray contrast media, and synthetic estrogens. The introduction and accumulation of pharmaceutical residues in the environment is a growing issue with implications for human health and ecosystems. Studies have suggested that pharmaceutical compounds are potentially harmful to aquatic organisms, affecting reproduction and development, even at very low concentrations (Hinck, et al., 2008, Vajda, et al., 2008).

In September 2015, the Strategic Approach to International Chemicals Management initiative of the United Nations Environment Programme, adopted environmentally persistent pharmaceutical pollutants as an emerging policy issue (SAICM, 2015). Given the nature of the problem, a multi-sectoral, multi-stakeholder approach to prevent, reduce and manage pharmaceuticals from entering the environment is needed. A proposed activity to reduce the risk of pharmaceuticals is the establishment and promotion of best management practices for disposal of unused and/or expired pharmaceuticals and raising awareness about the adverse effects of pharmaceuticals in the environment. This study analyzes survey data and examines the factors that could influence the likelihood of households participating in drug take-back programs. The information provided from this study will help better target program advertising campaigns for both awareness and participation.

3.1.1 Literature Review

Numerous studies have been published regarding human behavior and the environment. This field of study, known as environmental psychology, has tried to explain the complexity of direct and indirect environmental action trying to predict conservation behaviors based on particular attitudes towards the environment. One of the most studied issues is the difference between environmental awareness and pro-environmental behavior and actions. Although several authors have designed theoretical frameworks to try and explain the difference between environmental awareness and behavior, no convincing conclusions have been reached yet (Kollmuss and Agyeman, 2002).

A common belief in the 1970's was that increasing knowledge and awareness through education and communication campaigns would lead to a positive change in environmental behavior. Over the course of the decades, researchers have designed different models to explain why this relationship is not observed when analyzing environmental behavior. Factors included not only knowledge, but also the difference between indirect learning (e.g. school, advertising) and direct experience, sociodemographic components like social norms, cultural traditions and family customs (Rajecki, 1982), beliefs of consequences and social pressure (Ajzen and Fishbein, 1980), the possibility to act, and economic constraints (Fietkau and Kessel, 1981, Hines, et al., 1987). In practice, environmental behavior is so complex that it cannot be explained nor represented by a single model.

As most researches have concluded, environmental knowledge and environmental awareness can explain a small portion of environmental behavior, with at least 80% explained by situational and other internal factors (Kollmuss and Agyeman, 2002). Nonetheless, specific factors studied throughout the years have been found to exert either positive or negative influence on pro-environmental behavior. Regarding demographic factors, two variables have been found to be consistently correlated with environmental concern. Regardless of what dependent variable measure is used, younger people are, in general, more concerned about environmental quality (Klineberg, et al., 1998). Years of education has also been found to have a positive correlation with pro-environmental behavior. Better educated citizens will most likely have more knowledge about environmental issues as well (Blocker and Eckberg, 1997, Klineberg, et al., 1998, Kollmuss and Agyeman, 2002). In some cases, gender is included as one of the factors which influences environmental attitude. Usually, women have been associated with a higher environmental concern, given that they are more emotionally engaged than men, show more concern towards environmental destruction, and are more willing to change (Kollmuss and Agyeman, 2002, Kotchen, et al., 2009, Mohai, 1992, Stern, et al., 1993, Torgler, et al., 2008). However, some studies have found mixed evidence (Blocker and Eckberg, 1997, Klineberg, et al., 1998).

Economic factors have also been found to have an important effect on people's decisions towards the environment. The literature suggests a positive, although not conclusive, relationship between the value of environmental amenities and average income (Ferreira and Moro, 2013, Klineberg, et al., 1998, McConnell, 1997).

The determinants of environmental concern vary significantly depending on the assessment method, dependent variable used, and specific environmental behavior. A generalized concern for the environment is not usually a determining factor for following specific environmental behaviors. Individuals decide to express their concern in different ways, thus explaining why some people are engaged in some environmental issues and others are indifferent. The conservation literature suggests that researchers should focus their studies on attitudes specific to the environmentally friendly behavior in question, and not focus all their attention in general attitudes (Teisl and O'Brien, 2003). Attitudes are not the ones that determine behavior directly, but they do influence actions.

Studies on pharmaceutical take-back programs have found that people that are more aware of the consequences of improperly disposing pharmaceuticals in the environment are more likely to take their unwanted and unused medications to a collection center (Blom, et al., 1996, Kotchen, et al., 2009, Persson, et al., 2009, Tong, et al., 2011). The correlation between age and pharmaceutical disposal practices is consistent with research about other environmental behaviors, with younger adults more willing to pay for a medicine take-back program. Other factors that have been found to influence the decision to participate in a pharmaceutical collection program are gender (female) and political affiliation (democrat).

Qualitative choice models have commonly been used to forecast consumer demand for goods that are both not available and available in the market (Beggs, et al., 1981, Jung, 1993) and also to assess consumer preferences and choices (Koop and Poirier, 1994). The extension of these models to study environmental concern and different environmental behaviors has been common practices in the last couple of decades (Beggs, et al., 1981, Bestard and Nadal, 2007, Jung, 1993, Saphores, et al., 2006, Sønderskov and Daugbjerg, 2011, Teisl and O'Brien, 2003, Vicente-Molina, et al., 2013). In this study, we use an ordered probit model to assess the determinants of participation in a medicine take-back program in the Great Lakes region.

3.1.2 Objectives

The specific objectives of this analysis are to:

a) Assess the determinants of participation in medicine collection programs in the Great Lakes region.

b) Estimate the probability of likelihood of participation in a medicine collection program in the Great Lakes region.

3.1.3 Hypothesis

The participation of a household in medicine collection programs will be determined by their environmental awareness, presence of pharmaceuticals in their home, and socioeconomic characteristics. Specifically:

- Presence of unwanted pharmaceuticals in the household will have a positive correlation with participation in the program.
- Higher environmental awareness will have a positive correlation with participation in the program.
- Higher education will have a positive correlation with participation in the program.

3.2 Data and Methods

3.2.1 Data

The data used in this model was gathered from an online survey administered during the summer of 2015 in Indiana, Illinois, Michigan, Minnesota, Ohio and Wisconsin. The survey was designed to learn about medicine disposal practices and willingness to participate in a medicine take-back program. The target population included all individuals at least 18 years of age from households living in these states. The total number of respondents was 2,031, from which a total of 1,311 observations were considered for this analysis. The additional 720 observations were excluded from the analysis due to missing data. The complete survey can be found in Appendix A[3].

The dependent variable in the model is the likelihood to participate in a medicine take-back program. In the survey, participants were asked to indicate their likelihood to participate in an unwanted pharmaceutical collection program in the next 12 months by selecting an option from a 5-point scale; the answers included "Very likely", "Somewhat likely", "Neither likely nor unlikely", "Somewhat unlikely", and "Very unlikely". Twenty-four percent reported their participation in such programs to be either unlikely (16%) or somewhat unlikely (8%) in the following 12 months. About 25% of the sample population was uncertain, having reported they are neither likely nor unlikely to become participants. About half of the survey responders stated to be somewhat likely (23%), and very likely (25%) to use a pharmaceutical collection program in the coming year. For our analysis we collapsed the responses into 3 categories, "Likely to participate", "Neither likely nor

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[3] The survey can also be retrieved online at: https://purdue.qualtrics.com/SE/?SID=SV_em724dM9PhaewHr

unlikely to participate”, and “Unlikely to participate”. Fifty-six percent of the respondents expressed their likelihood to participate in the future (*like*), 26% were neither likely nor unlikely to participate (*neutral*), and 18% claimed it was unlikely they would participate in a collection program (*unlike*). In Table 3.1 the likelihood of participation in a pharmaceutical collection program by gender is summarized, where 58.97% of the male and 54.31% of female respondents expressed their likelihood to participate in a program in the coming year. Table 3.2 summarizes participation per state, where a higher percentage of Illinois residents indicated they are likely to participate (61.97%), followed by Indiana with 56.82% of sample residents.

Table 3.1: Likelihood of Participation in a Pharmaceutical Program per Gender.

Variable [%]	Unlikely	Neutral	Likely
Female	18.14	27.54	54.31
Male	17.69	23.34	58.97
Total [%]	18.00	26.24	55.76

Table 3.2: Likelihood of Participation in a Pharmaceutical Program per State.

Variable [%]	Unlikely	Neutral	Likely
IL	15.02	23.00	61.97
IN	15.15	28.03	56.82
MI	18.82	27.06	54.12
MN	25.97	32.47	41.56
OH	21.10	26.61	52.29
WI	20.45	28.03	51.52
Total [%]	18.00	26.24	55.76

The independent variables considered for the model were grouped into socio-economic variables (***Dem***), environmental practices of the household (***Env***), variables related to unwanted pharmaceuticals (***Phar***), and location (***Geo***).

Environmental Practices (***Env***)

The environmental practices variables consist of environmental awareness and the number of environmental programs the household is currently engaged in. These variables were included to assess the portion of environmental behavior explained by environmental awareness and environmental knowledge. As a proxy for environmental awareness, we asked each subject how important environmental quality was for them in a 5-point scale. Answer options included "Extremely important", "Very important", "Neither important nor unimportant", "Very unimportant", and "Not important at all". Responses where consolidated into 3 categories: important (*e.imp*), neutral (*e.ntrl*) and unimportant (*e.unimp*). Most people (84%) indicated environmental quality was important for them, while 2% of respondent thought it was unimportant. About 14% of the individuals expressed a neutral perception of environmental quality. Given the strong relation between the medicine take-back programs with environmental concerns, we expect a positive effect between environmental importance and participation in such programs.

In the survey, households were also asked about their participation in different environmentally friendly programs including recycling, composting, water conservation, energy conservation, or use of environmentally friendly products. In our model, we defined the variable as the total number of programs each household currently participates in (*#envp*). On average, households are involved in 3 programs. Of the sampled population, 13.73% participates in one of these activities, 20.37% are engaged in two of these programs, 27.61% in three programs, 28.99% in four programs, and 9.31% in all five activities. Recycling and energy conservations are the most common practices, with 83.8% and 80.5% respectively of the sample population engaged in these activities. Composting is the least common environmental practice indicated; only 23.4% of the households are doing it. This variable (*#envp*) is expected to be positive because the more environmentally friendly programs households are enrolled in, we assume the more environmentally conscious the household is, and thus we expect them to be more likely to participate in an unwanted pharmaceutical collection program. Figure 3.1 show the proportion of the number of environmental programs and type of programs, individuals are engaged in.

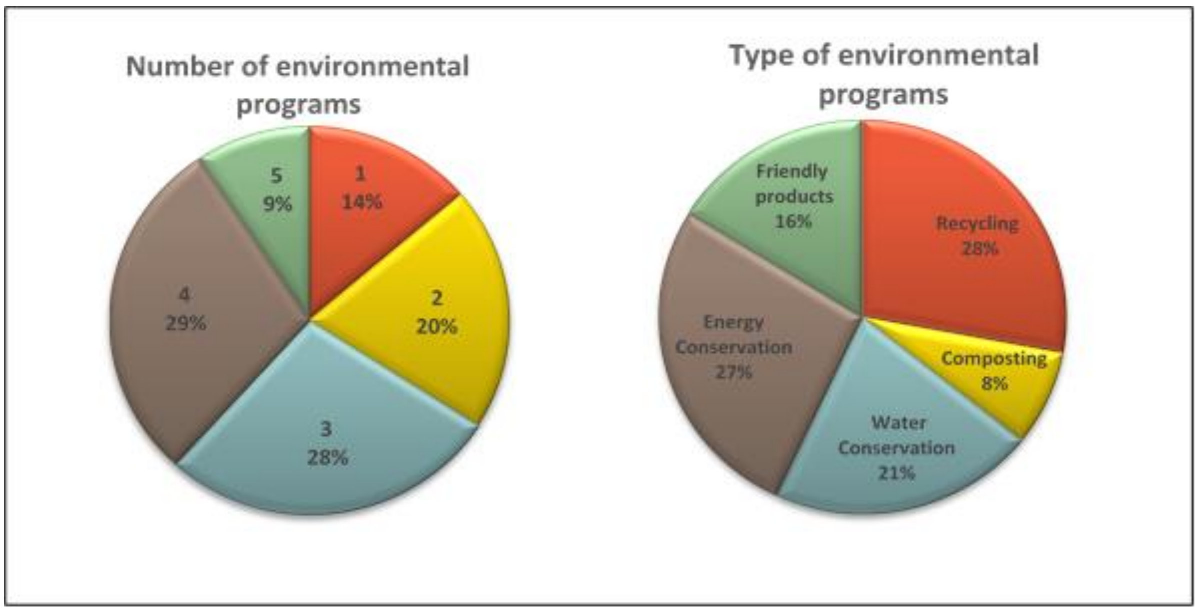

Figure 3.1: Number and Type of Environmental Programs Households are Engaged in.

Unwanted Pharmaceuticals ***(Phar)***

The unwanted pharmaceutical ***(Phar)*** variables were included to account for the specific attitudes related to unwanted pharmaceutical collection programs. Participation is associated with the presence of unused pharmaceuticals in the household. To account for the effect of the presence of unwanted medicines in the household, 3 variables, summarized in Table 3.3, were considered. The first variable related to households having had unwanted drugs over the last 12 months (*unmed*). For this binary variable (Yes/No), 75% of respondents answered positively, and 25% reported not having unwanted or unused medications over the last year. Given that individuals with unwanted pharmaceuticals in their home are the potential users of the program, a positive coefficient was expected. The number of different prescriptions users are likely to dispose of (*#Rx*) were also included. The mean number or prescriptions from the sample population was 2.27 prescriptions per visit. Our assumption was that the more prescriptions a user is likely to drop off is correlated with the number of prescriptions available in their households, and hence they would obtain a higher utility from participating in medicine collection programs. It is also anticipated that those people that have previously participated in a program would be more likely to continue participating in the future if they considered the program valuable. To assess this claim, we included a dummy variable for those that had previously participated in a take-back program (*part*). Approximately 72% of the sample population had not participated in a program before.

Table 3.3: Summary of Unwanted Pharmaceutical (***Phar***) Variables.

Variable	Yes	No	Mean
Unmed [%]	75.36	24.64	
Part [%]	27.61	72.39	
Number Prescriptions (#Rx)			2.27

Socio-economic Variables (***Dem***)

To control for socio-economic differences and economic constraints, we included average household income, education, age and gender into the model. The average annual household income was separated into 5 categories. The categories were defined as: $0.00-$30,000 (*inc0*), $30,001-$45,000 (*inc30*), $45,001-$60,000 (*inc45*), $60,001-$75,000 (*inc60*), and over $75,000 (*inc75*). The percentages of respondents per category are: 26% (*inc0*), 17.2% (*inc30*), 16.6% (*inc45*), 13.3% (*inc60*) and 26.9% (*inc75*). The median annual household income falls in the range of $45,001 - $60,000 USD, consistent with the 2014 Median Annual Household Income for the United States (U.S. Census Bureau, 2014). The literature suggests a positive, although not conclusive, relationship between the value of environmental amenities and average income (Ferreira and Moro, 2013, Klineberg, et al., 1998, McConnell, 1997). Hence, it is expected that households in a higher income groups are more likely to participate in a medicine collection program. In Table 3.4 the composition of the dataset per income group and likelihood to participate are summarized.

Table 3.4: Composition of Data Set per Income Group and Likelihood of Participation in a Pharmaceutical Program.

Variable [%]	Unlikely	Neutral	Likely	Total [%]
Inc0	6.79	8.31	10.91	26.01
Inc30	3.66	5.03	8.54	17.24
Inc45	2.14	4.50	9.92	16.55
Inc60	1.68	2.36	9.23	13.27
Inc75	3.74	6.03	17.16	26.93
Total [%]	18.00	26.24	55.76	100.00

In addition to income, education can also be key in increasing environmental awareness (Blocker and Eckberg, 1997, Klineberg, et al., 1998, Kollmuss and Agyeman, 2002). Consequently, a dummy variable for those participants who have at least a college degree (*edu*) was included in the model. As shown in Table 3.5, 66% of the sample population has obtained at least a college degree, while for 33%, their highest level of completed education is high-school. In line with the literature, the assumption is that the estimated parameter would have a positive sign.

Table 3.5: Composition of Data Set Given Education and Likelihood of Participation in a Pharmaceutical Program.

Variable [%]	Unlikely	Neutral	Likely	Total [%]
Edu=0	7.32	10.30	15.41	33.03
Edu=1	10.68	15.94	40.35	66.97
Total [%]	18.00	26.24	55.76	100.00

Previous studies have found a negative correlation between environmental preferences and age (Klineberg, et al., 1998, Torgler, et al., 2008). Three age groups ranging from 18-45 years old (*age18*), which compromise 52.6%, 46-65 years old (*age46*), accounting for 32.4% and over 65 years old (*age65*) representing 15% of the sample population, were included. The expectation is that younger adults are more likely to get rid of their unwanted medications through a collection program. This variable is summarized in Table 3.6.

The general consensus regarding gender is that women's concern towards the environment is stronger than men's. This association has been found in several studies (Kotchen, et al., 2009, Mohai, 1992, Stern, et al., 1993, Torgler, et al., 2008). However, some studies have found mixed evidence (Blocker and Eckberg, 1997, Klineberg, et al., 1998). To test this hypothesis, we included a dummy to assess the effect of gender in our model (*male*), where the dummy was 1 if the respondent was a man. Thirty-one percent of individuals are male, and 69% female. In Table 3.1, the likelihood of participation in a pharmaceutical program for each gender is summarized, while Table 3.7 shows the composition of the whole sample population by gender and likelihood to participate.

Table 3.6: Composition of Data Set Given Age and Likelihood of Participation in a Pharmaceutical Program.

Variable [%]	Unlikely	Neutral	Likely	Total [%]
Age18	9.00	12.51	31.05	52.56
Age46	5.72	9.38	17.32	32.42
Age65	3.28	4.35	7.40	15.03
Total [%]	18.00	26.24	55.76	100.00

Table 3.7: Composition of Data Set Given Gender and Likelihood of Participation in a Pharmaceutical Program.

Variable [%]	Unlikely	Neutral	Likely	Total [%]
Female	12.51	18.99	37.45	68.95
Male	5.49	7.25	18.31	31.05
Total [%]	18.00	26.24	55.76	100.00

Location (***Geo***)

Finally, we included dummy variables for each of the states where the survey was applied (*IN, OH, WI, MI, IL, MN*). The goal was to assess if there was any difference in the likelihood to participate across geographical regions. The composition of the data per State and indicated likelihood to participate is shown in Table 3.8.

Table 3.8: Composition of Data Set per State and Likelihood of Participation in a Pharmaceutical Program.

Variable [%]	Unlikely	Neutral	Likely	Total [%]
IN	4.88	7.48	20.14	32.49
IL	3.05	5.64	11.44	20.14
MI	1.22	1.75	3.51	6.48
MN	1.53	1.91	2.36	5.80
OH	5.26	6.64	13.04	24.94
WI	2.06	2.82	5.26	10.14
Total [%]	18.00	26.24	55.76	100.00

3.2.2 Methodology: Ordered Logit Model (OLM)

Ordinal variables in econometrics can be defined as those where a mapping from an underlying, naturally preference scale is translated into an ordered observed outcome. The order matters, which means they can be ranked, but the distance between one category and the other is not known. Thus, when used as a dependent variable, they violate the assumptions of the Linear Regression Models (*e.g.* OLS). McKelvey and Zavoina (1975) and McCullagh (1980) introduced the ordinal regression model to social sciences for the analysis of ordered, categorical, non-quantitative choices, outcomes and responses, where the focus of the model was the analysis of the odds of choosing one response category versus another.

The ordinal regression model is usually presented as a latent variable model, given that it is an underlying random utility model. The structural model is defined as:

$$y_i^* = \boldsymbol{x_i\beta} + \varepsilon_i, i = 1, \dots, n. \tag{4.1}$$

where $\boldsymbol{x_i}$ is the vector set of independent variables, k. $\boldsymbol{x_i}$ is assumed to be strictly independent of the random error, ε, for every observation i, and $\boldsymbol{\beta}$ is a vector of k parameters to be estimated.

The independent variable measuring the random utility, y_i^*, can be divided into J ordinal categories, where the cut points τ_m to τ_J are estimated in the following way:

$$\begin{aligned} y_i^* &= 0 \text{ if } \tau_{m-1} \leq y_i^* < \tau_{m,} \\ &= 1 \text{ if } \tau_m \leq y_i^* < \tau_{m+1,} \\ &= 2 \text{ if } \tau_{m+1} \leq y_i^* < \tau_{m+2,} \\ &= \dots \\ &= J \text{ if } \tau_{J-1} \leq y_i^* < \tau_{J,} \end{aligned} \tag{4.2}$$

The thresholds are an important element of the model since they divide the range of utility into cells. An important assumption of the model is that these threshold values are the same for everyone (Greene and Hensher, 2010).

For the purpose of our analysis, the empirical model for the variable groups was defined as:

$$y_i^* = \boldsymbol{Env_i}\boldsymbol{\beta_{Env}} + \boldsymbol{Phar_i}\boldsymbol{\beta_{Phar}} + \boldsymbol{Dem_i}\boldsymbol{\beta_{Dem}} + \boldsymbol{Geo_i}\boldsymbol{\beta_{Geo}} + \varepsilon_i, \quad i = 1, \ldots, n. \quad (4.3)$$

where $\boldsymbol{Env_i}$ is the vector set of independent environmental variables including *e.imp, e.ntrl* and *#envp;* $\boldsymbol{Phar}$ is the vector set of pharmaceutical related variables including *unmed, part* and *#Rx;* $\boldsymbol{Dem}$ is the vector set of socioeconomic variables including *inc30, inc45, inc60, inc75, edu, age18, age46,* and *male;* and $\boldsymbol{Geo}$ is the vector of states *IN, OH, WI, MI,* and *IL.* The dependent variable (y_i^*) selected in the model was the naturally ordered unobservable likelihood to participate. The choices from the surveyed individuals was censored into three *J* categories: *unlike, neutral,* and *like.* Responses were censored into 3 categories to increase the number of observations for the lowest category (*unlike*) and improve the asymptotic approximation without losing any information from the ordered groups. Doing so does not affect the slope parameters, only the intercepts (Greenland, 1994, Peterson and Harrell, 1988). Some researchers have suggested a loss of efficiency when collapsing categories in small sample, especially when converting into a dichotomous choice (Murad, et al., 2003).

An important assumption that is made for the Ordered Regression Models is the proportional odds assumption. This assumption implies that the slope coefficients are identical across each regression. This means each probability curve for each level differs only in being shifted to the left or right, meaning the $\boldsymbol{\beta}$'s are the same for each threshold set of equations. Assuming the coefficients are equal, implies the estimated coefficients should be close. If the parallel regression condition is not met, alternative models that do not impose this constraint, such as the generalized ordered logit, should be considered. To test this assumption in our model, we used a Wald test by Brant (1990), which tests the parallel regression assumption for each dependent variable individually. The null hypothesis implies that *J*-1 binary models can be estimated separately, and each would have its own constant term, but the same slope vector. The hypotheses are defined as:

$$H_0 = \boldsymbol{\beta_q} - \boldsymbol{\beta_1} = 0, \ \ q = 2, \dots, J-1.$$

$$H_a = \boldsymbol{\beta_q} - \boldsymbol{\beta_1} \neq 0, \ \ q = 2, \dots, J-1. \tag{4.4}$$

For our model, we used the “Brant” Stata command developed by Long & Freese (2014). The resulting Chi-square from the Brant model for all variables was 15.08, with a p> Chi-square of 0.72 with 19 degrees of freedom. The test result fails to reject the null hypothesis, suggesting the ordered model specification is supported by the data. Detailed results can be seen in Table 3.9.

The OLM is a maximum likelihood estimation, meaning the coefficient estimations from the model are nonlinear. Unlike Ordinary Least Squares estimation, the model does not directly describe the relationship between the dependent variables and the independent variables, but instead describes the probabilities of outcomes. Therefore, the interpretation of the coefficients differs from a traditional least square regression model and may become a challenge when summarizing the effects of the independent variables. A common approach is to estimate the probability of an observed outcome for a given value of x.

$$\Pr(y = m|x) = Pr(\tau_{m-1} \leq y^* < \tau_{m,}|x) \tag{4.5}$$

Table 3.9: Brant Test of Parallel Regression Assumption Results from Stata.

Vector	Variable	Chi^2	$p>chi^2$
	All	15.08	0.72[4]
Env	*e.ntrl*	0.66	0.42
	e.imp	0.02	0.88
	#envp	0.04	0.85
Phar	*part*	1.74	0.19
	unmed	0.12	0.73
	#Rx	1.69	0.19
Dem	*inc30*	0.08	0.78
	inc45	0.07	0.79
	inc60	2.20	0.14
	inc75	0.11	0.74
	edu	0.30	0.58
	age18	1.35	0.25
	age46	0.00	1.00
	male	0.39	0.53
Geo	*IN*	0.00	1.00
	OH	0.80	0.37
	WI	0.03	0.86
	MI	0.34	0.56
	IL	0.34	0.43

[4] A significant test statistic provides evidence that the parallel regression assumption has been violated.

All estimations were done using STATA 13.1 and Long and Freese's (2014) post-estimation commands for ordinal outcomes.

3.3 Results and Discussion

The estimates for the Ordered Logit Model, summarized in Table 3.10, indicates:

$$
\begin{aligned}
y_i^* = {} & 0.25e.ntrl + 0.91e.imp + 0.15\#envp + 1.78part + 0.55unmed + 0.34\#Rx + 0.14inc30 \\
& + 0.54inc45 + 0.89inc60 + 0.28inc75 + 0.15edu + 0.27age18 + 0.20age46 \\
& + 0.16male + 0.63IN + 0.57OH + 0.17WI + 0.51MI + 0.86IL + \varepsilon_i.
\end{aligned}
$$

$$
\begin{aligned}
& y = 0 \; if \; 0 \le y^* < 2.16, \\
& y = 1 \; if \; 2.16 \le y^* < 3.78, \qquad (4.6) \\
& y = 2 \; if \; 3.78 \ge y^*.
\end{aligned}
$$

These thresholds together with the predicted probabilities for the OLM model are illustrated in Figure 3.2.

The model converges at -1,088.91, which represents the maximized value of the log-likelihood function, and -1,291.912 for the log-likelihood for the intercept-only. A chi-square test of the log-likelihoods with 19 Degrees of Freedom indicates a rejection of the hypothesis of no regression.

For logistic models, evaluating goodness of fit is not related with how well the model predicts the outcome variable, but with the log-likelihood of the model. Yet, pseudo R^2s with a similar scale to R^2, have been developed to assess the model fit. Just as OLS regressions, a higher value indicates a better model fit, but they are not comparable one to the other, or even between different pseudo R^2s. For this model, McFadden's (1973) pseudo R^2 is 0.1571, which compares a model with just the intercept to a model with all the parameters. McKelvey and Zavoina's (1975) pseudo R^2, which measures the ratio of the regression variation to the total variation in the latent regression, is 0.385.

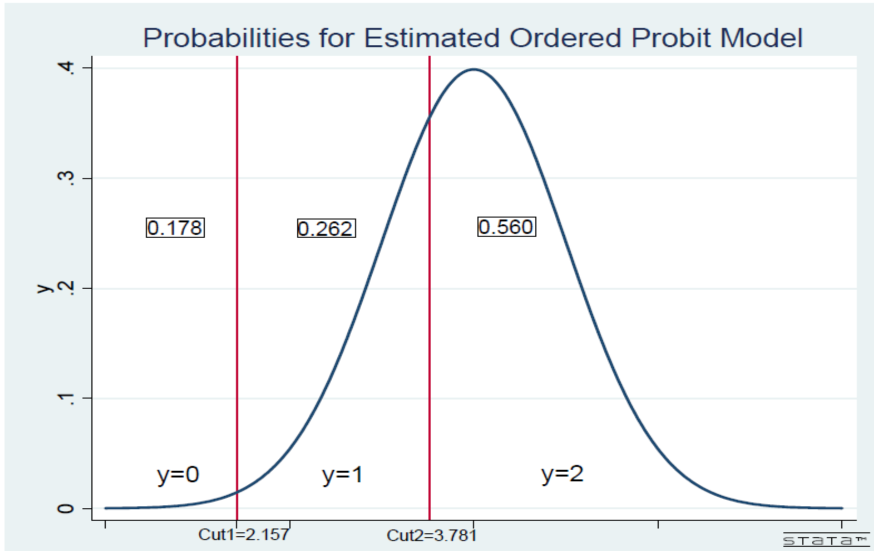

Figure 3.2: Estimated Ordered Probit Model. (Adapted from Greene and Hensher, 2010)

The results from the analysis suggest likelihood of participation in a medicine take-back program is influenced by the number of environmental programs participants are enrolled in (*#envp*), previous participation (*part*), presence of unwanted pharmaceuticals in the house (*unmed*), the number of prescriptions likely to dispose of (*#Rx*), average household income between $45,000-$75,000 (*inc45*), and being a resident from Illinois (*IL*), at a statistically significant level of 1%. The importance towards the environment (*e.imp*) and residents from Indiana (*IN*) and Ohio (*OH*) are significant at a 5% significance level, while annual household income higher than $75,000 (*inc75*) is significant at a 10% significance level. The sign or magnitude of the relationship cannot be determined from the coefficients, since neither of them can be directly interpreted given that there is no conditional mean function, $E(y|x)$, to analyze (Greene and Hensher, 2010). Inference about the threshold parameters do not provide any useful insight either. By definition, the coefficients will be statistically significant, otherwise the underlying ordering assumption would not be valid, suggesting that the categories should be combined, changing the specified model.

For the estimated model, the average partial effects (APEs) were calculated for the purpose of interpreting the coefficients. The APEs evaluate the marginal effects for each individual, and then uses the sample average of the computed effects. In non-linear models with discrete variables, the average partial effects are of more interest than the partial effects of the average because they are representative of the data (Papke and Wooldridge, 2008). The average partial effects are a function of all the parameters in the model, the data and the variable of interest.

From Table 3.10, environmental importance has a positive effect on likelihood to participate in a pharmaceutical collection program. The marginal effect is higher for those that consider the environment important and stated being likely to participate in the future (17%) that those that are neutral regarding their likelihood of participation in the future (6%). Likewise, the number of environmental programs households are participating in has a higher marginal effect (2.7%) on the likelihood to participate in a medicine take-back program compared to being neutral (0.1%) or not likely to participate (1.8%). Among the environmental factors, the importance that households attach to the environment has a relatively higher influence on likelihood to participate than neutral environmental importance and participation in other environmental programs. This difference might indicate that participation in ecological programs can be linked with a particular environmental issue the individual is concerned about, thus participating in a program addressing a different environmental aspect (i.e. pharmaceutical contamination) is of no interest to them, while environmental awareness is a more general behavior. Another plausible explanation for the difference in marginal effect is the difference between observed and stated preference variables. The number of environmental programs a household is engaged in, is an observed factor in the sense that these are activities they are actually practicing. However, the importance an individual attributes to the environment is a stated preference. It has been widely suggested in the literature that stated preference can be overestimated when compared to observed behavior, since stating a preference will not necessarily determine action. This may explain why although a high percentage of the sample population with a high environmental awareness stated being likely to participate in a medicine collection program in the future, only a small fraction of the population has actually participated in the past.

Regarding the pharmaceutical variables, previous involvement in a program has the highest positive effect on future participation. The marginal probability of participation is about 33%. Although take-back medicine programs are free, users incur an opportunity cost of learning how these programs work and where the disposal centers are located. Thus, for individuals that have previously participated in such programs, the opportunity cost of learning about these programs is lower than the perceived cost of environmental damage, medicine abuse and/or accidental poisoning. Having unwanted medication at home would result in about 10% increase in the probability of likelihood of participation in a medicine collection program, while the effect of the number of prescriptions is 6%.

Table 3.10: Marginal Effects of Likelihood to Participate

	Variable	Coefficient	Marginal Effects		
			Not Likely	Neutral	Likely
Env	*e.ntrl*	0.248 (0.427)	-0.030 (0.052)	-0.016 (0.027)	0.046 (0.079)
	e.imp	0.908** (0.416)	-0.111 (0.051)	-0.057 (0.027)	0.169 (0.077)
	#envp	0.146*** (0.053)	-0.018 (0.006)	-0.009 (0.003)	0.027 (0.010)
Phar	*Part*	1.776*** (0.169)	-0.218 (0.022)	-0.112 (0.010)	0.330 (0.027)
	Unmed	0.554*** (0.135)	-0.068 (0.016)	-0.035 (0.009)	0.103 (0.025)
	#Rx	0.342*** (0.045)	-0.042 (0.006)	-0.022 (0.003)	0.063 (0.008)
Dem	*inc30*	0.138 (0.175)	-0.017 (0.021)	-0.009 (0.011)	0.026 (0.033)
	inc45	0.543*** (0.183)	-0.067 (0.022)	-0.034 (0.012)	0.101 (0.034)
	inc60	0.887*** (0.208)	-0.109 (0.026)	-0.056 (0.013)	0.165 (0.038)
	inc75	0.283* (0.169)	-0.035 (0.021)	-0.018 (0.011)	0.053 (0.031)
	educ	0.153 (0.126)	-0.019 (0.015)	-0.010 (0.008)	0.029 (0.023)
	age18	0.269 (0.174)	-0.033 (0.021)	-0.017 (0.011)	0.050 (0.032)
	age46	0.198 (0.182)	-0.024 (0.022)	-0.012 (0.012)	0.037 (0.034)
	Male	0.158 (0.132)	-0.019 (0.016)	-0.010 (0.008)	0.029 (0.024)
Geo	*IN*	0.631** (0.264)	-0.077 (0.032)	-0.040 (0.017)	0.117 (0.049)
	OH	0.572** (0.256)	-0.070 (0.031)	-0.036 (0.016)	0.106 (0.047)
	WI	0.166 (0.293)	-0.020 (0.036)	-0.010 (0.019)	0.031 (0.054)
	MI	0.507 (0.328)	-0.062 (0.040)	-0.032 (0.021)	0.094 (0.061)
	IL	0.864*** (0.254)	-0.106 (0.031)	-0.055 (0.016)	0.161 (0.047)
	cut1_cons	2.157*** (0.511)			
	cut2_cons	3.781*** (0.519)			
	N	1,311			

* *p*<0.1; ** *p*<0.05; *** *p*<0.01

All income levels have a positive correlation with a positive likelihood to participate. The biggest effect though, is for those participants with a reported annual household income of $60,000 to $75,000. They are 17% more likely to participate in a take-back program while participants in the $45,000-$60,000 range are about 10% likely to participate. Higher income has been associated with a positive correlation towards pro-environmental concern, which might explain the higher marginal effect at this level. Some studies have suggested though, that at the upper end of the distribution, pro-environmental behavior drops off. This might explain why the marginal effect in the highest income level is 12% less than the $60,000-$75-000 income group.

Regarding location, the highest marginal effect for likelihood of participation is in Illinois with 16.1%, followed by Indiana with 11% and Ohio with 10.6%. Illinois has the highest population between the 6 states analyzed. Approximately 40% of the population lives in Cook County, the second most populated in the U.S. It is geographically located along the shores of Lake Michigan, which has received the most attention among the Great Lakes regarding pharmaceutical pollution. Trace levels of APIs have also been found in drinking water sources for the city of Chicago. Concerns about the implications for human health among a densely populated area, and the economic losses from pollution to the lake have prompted the state to actively work to address these issues since the early 2000's. Even though it failed to pass, in 2005-2006 a Bill to establish a pilot medical return programs was debated. Since then, the Illinois Environmental Protection Agency has launched an initiative in collaboration with public and private sector to promote environmentally responsible disposal programs. The increased advertising of the concern of pharmaceuticals in surface and drinking water, the education and awareness campaigns launched throughout the region, and the contribution between public and private sectors could have resulted in a higher awareness of the issue among the population. Furthermore, Illinois is a fairly liberal state. A study in California found that individuals with democrat affiliation were 13% more likely to participate in a medicine take-back program (Kotchen, et al., 2009). Thus, the political affiliation could also play a role in the higher marginal effect compared to other states.

One of the suggested drivers of a marginal effect of 11% and 10% among Indiana and Ohio residents is the drug abuse problems in these states. The main drivers of overdose deaths in the U.S. since 2000 are opioids, which include prescription pain relievers. In 2014, Ohio was the 5th state in the country with the highest rate of death due to overdose, while Indiana ranked 16th. From 2013 to 2014, Indiana had a statistically significant increase of fatalities attributed to this cause. Indiana's proximity to Illinois and organizations such as IISG working in both states could also play an important role.

For the OLM, another useful way of interpreting the results and measuring the fit of the model to the data is to assess the model's ability to predict the outcomes. In Table 3.11, the sample data indicates 18% of the consumers are not likely to participate in a take-back medicine program, 26% are neutral, and 55.8% will likely participate. The model's predicted probabilities are very close to those observed for every category from the estimation sample. Using the whole dataset (2,030 observations), the model's forecasting power is still good, with the predictions of each outcome falling within the standard deviation.

Table 3.12 shows that the predicted probability of neutral participation remains very close to the percentage of responses from the survey, with a variation of only -1.7%.

Meanwhile, the model's prediction for households being likely to participate is overestimated by 7.7% and those not willing to participate underestimated by 6%. This is probably driven by the difference between the survey sample and model sample observations.

Table 3.11: Percentage of Likelihood to Participate and Predicted Probabilities Calculated from OLM Sample.

Variable	Observations	Respondents [%]	Predicted probabilities	
		Mean	Mean	St Dev
Not Likely	1311	0.18	0.18	0.16
Neutral	1311	0.26	0.26	0.12
Likely	1311	0.56	0.56	0.25

Table 3.12: Percentage of Likelihood to Participate from Survey Sample

Variable	Observations	Mean
Not Likely	2031	0.24
Neutral	2031	0.28
Likely	2031	0.48

After calculating the predicted probabilities from the general model, we calculated the individual predicted probabilities for both men and women from a nationally representative sample: mean age of 38 years old, median income of $51,759 and without a college degree. We also estimated the individual probabilities for the sample with the same characteristics but with a college degree. The individual estimated probabilities are summarized in Table 3.13. It can be observed that the model predicts individuals age 18-45 with annual household income from $45,000 - $60,000 are more likely than the rest of the population to participate in a medicine program. In particular, an increase in education increases the probability of likelihood of participation in both men and women by about 3.3% and 3.5%, respectively. These findings align with the suggestions in the literature where more educated people are more likely to engage in pro-environmental behavior.

According to the model predictions, men in these age and income ranges, are also more likely than women to participate in a collection program by 3.6% for those without a college degree and 3.4% with a college degree. These findings contrast with previous studies of general environmental awareness where women have been found to be more likely to participate than men (Kollmuss and Agyeman, 2002, Kotchen, et al., 2009, Mohai, 1992, Stern, et al., 1993, Torgler, et al., 2008). Other studies assessing pro-environmental behavior have found mixed evidence regarding the effect of gender (Blocker and Eckberg, 1997, Klineberg, et al., 1998). Blocker and Eckberg (1997) have suggested that higher environmental concern of women does not translate into significant higher participation in environmental actions than men.

Table 3.13: Individual Predicted Probabilities for Nationally Representative Sample

Individual Characteristics	Participation		
	Not Likely	Neutral	Likely
Women age 18-45, annual income $45-$60 MUSD, no college degree	0.10	0.26	0.63
Men age 18-45, annual income $45-$60 MUSD, no college degree	0.09	0.24	0.67
Women age 18-45, annual income $45-$60 MUSD, with college degree	0.09	0.24	0.67
Men age 18-45, annual income $45-$60 MUSD, with college degree	0.08	0.22	0.70

From a policy perspective, policymakers can influence environmental concern through different programs and education campaigns. However, they have little influence on socio-demographic conditions in the short run. For this reason, the individual predicted probabilities of likelihood of participation were calculated given the respondents' concern for the environment, and the number of environmental programs they are enrolled in. Both Table 3.14 and Table 3.15 summarize the results. From Table 3.14, the predicted probabilities indicate a high predicted probability of likelihood to participate in a medicine collection program in the future, irrespective of environmental concern. Those that consider the environment important have a higher predicted probability of likelihood to participate (62.5%) compared to neutral (46.3%) and unimportant (40.2%). Given that the predicted probability of possible participation estimated by the model increases as individuals become more concerned for the environment, policymakers have an opportunity to influence participation through environmental awareness interventions.

Table 3.14: Predicted Probabilities of Participation Given Environmental Concern

Environmental concern	Participation		
	Not Likely	Neutral	Likely
Important	0.11	0.27	0.63
Neutral	0.19	0.35	0.46
Unimportant	0.23	0.37	0.40

In Table 3.15, the predicted probabilities are calculated given the number of environmental programs households are engaged in for only those users with neutral concern for the environment. The results show that, the more programs a household participates in, the more likely they will consider returning their medications through a disposal program. For example, although a household is neutral regarding environmental concern, the model predicts they are 71.2% more likely to participate in a medicine collection program if they are already involved in 5 environmentally friendly programs. Those engaged in 4 programs are 68% more likely and even those engaged in 1 program are about 58% likely to participate in a medicine take-back program. This observation was previously suggested by Teisl and O'Brien, who argued that if participating in more environmental program has significant impacts on environmentally friendly behavior, then policies and programs promoting these kind of activities as a whole should be considered when discussing actions to promote environmental sustainability (Teisl and O'Brien, 2003).

Table 3.15: Individual Predicted Probabilities Based on Participation in Environmental Programs for Consumers with Neutral Environmental Concern

Participation in Environmentally Friendly Programs	Outcome Category of Participation		
	Not Likely	Neutral	Likely
One Program	0.13	0.30	0.58
Two Programs	0.11	0.28	0.61
Three Programs	0.10	0.26	0.65
Four Programs	0.09	0.24	0.68
Five Programs	0.07	0.22	0.71

3.4 Policy Implications and Conclusions

Unwanted and unused medications stored in households have been associated with prescription abuse and accidental poisoning. The improper disposal of these substances has also been linked with surface and ground water pollution that affects ecosystems; it may also have an effect on humans through drinking water. Medicine take-back programs have been created to mitigate these problems.

This study assessed the determinants of household participation in a pharmaceutical collection program. The results show that presence and number of unwanted pharmaceuticals in the household are important factors that influence participation. Income is another factor that affects the household’s decision. The model indicated the highest marginal effect for individuals with an annual household income of $60,000-$75,000. A number of programs have targeted their advertisement campaigns to older sectors of the population because of the higher incidence of prescriptions in this group. In contrast, the model suggests a higher marginal effect for young adults. These findings suggest that if program providers target education and awareness campaigns at younger individuals as well, household participation is likely to increase at a higher rate, all other things equal.

Another finding from the analysis is that environmental awareness does play a major role in determining positive stated likelihood to participate in this environmentally friendly practice. When estimating the predicted probabilities of participation for those that consider themselves neutral regarding the environment and given the level of participation in other environmental programs, the study suggests there is a positive correlation between the probability of participation in a medicine collection program with the more environmentally friendly programs the household is already engaged in. Policymakers and program providers can utilize these findings by creating synergies with other environmental programs and leverage on existence awareness campaigns.

The study results reflect a high level of participation in a drug collection program over the coming 12 months. However, in practice only a small percentage of the population has attended single day or permanent collection centers to dispose of their medications. This difference in stated vs. observed preferences indicates results should be interpreted with caution, bearing in mind the methodological limitation of the theoretical framework to estimate reality.

3.5 List of References

Ajzen, I., and M. Fishbein. 1980. *Understanding attitudes and predicting social behavior:* 1st ed. Pearson.

Beggs, S., S. Cardell, and J. Hausman. 1981. "Assessing the potential demand for electric cars." *Journal of Econometrics* 17:1-19.

Bestard, A.B., and J.R. Nadal. 2007. "Modelling environmental attitudes toward tourism." *Tourism Management* 28:688-695.

Blair, B.D., Crago, J.P., Hedman, C.J. and Klaper, R.D. 2013. "Pharmaceuticals and personal care products found in the Great Lakes above concentrations of environmental concern." *Chemosphere* 93:2116-2123.

Blocker, T.J., and D.L. Eckberg. 1997. "Gender and Environmentalism: Results from the 1993 General Social Survey." *Social Science Quarterly* 78:841-858.

Blom, A., J. De Bruijn, and F. Van de Vaart. 1996. "How consumers deal with the remainders of unused prescription drugs." *Pharmaceutisch Weekblad* 131:102-107.

Brant, R. 1990. "Assessing Proportionality in the Proportional Odds Model for Ordinal Logistic Regression." *Biometrics* 46:1171-1178.

Ferreira, S., and M. Moro. 2013. "Income and preferences for the environment: evidence from subjective well-being data." *Environment and Planning A* 45:650-667.

Fietkau, H.-J., and H. Kessel. 1981. "Umweltlernen: veraenderungsmoeglichkeite n des umweltbewusstseins." *Modell-Erfahrungen (Koenigstein, Hain).*

Greene, W.H., and D.A. Hensher. 2010. *Modeling ordered choices: A primer*: Cambridge University Press.

Greenland, S. 1994. "Alternative models for ordinal logistic regression." *Statistics in medicine* 13:1665-1677.

Hinck, J.E., Blazer, V.S., Denslow, N.D., K.R., Echols, Gale, R.W., Wieser, C., May, T.W., Ellersieck, M., Coyle, J.J. and Tillitt, D.E. 2008. "Chemical contaminants, health indicators, and reproductive biomarker responses in fish from rivers in the Southeastern United States." *Sci Total Environ* 390:538-557.

Hines, J.M., H.R. Hungerford, and A.N. Tomera. 1987. "Analysis and synthesis of research on responsible environmental behavior: A meta-analysis." *The Journal of environmental education* 18:1-8.

Hughes, S.R., P. Kay, and L.E. Brown. 2012. "Global synthesis and critical evaluation of pharmaceutical data sets collected from river systems." *Environmental science & technology* 47:661-677.

Jung, T.Y. 1993. "Ordered logit model for residential electricity demand in Korea." *Energy Economics* 15:205-209.

Klineberg, S.L., M. McKeever, and B. Rothenbach. 1998. "Demographic Predictors of Environmental Concern: It Does Make a Difference How It's Measured." *Social Science Quarterly* 79:734-753.

Kollmuss, A., and J. Agyeman. 2002. "Mind the Gap: Why to people act environmentally and what are the barriers to pro-environmental behavior?" *Environmental Education Research* 8.

Koop, G., and D. Poirier. 1994. "Rank-ordered logit models: An empirical analysis of Ontario voter preferences." *Journal of Applied Econometrics* 9:369-388.

Kotchen, M., Kallaos, J., Wheeler, K., Wong, C. and Zahller, M. 2009. "Pharmaceuticals in wastewater: Behavior, preferences, and willingness to pay for a disposal program." *Journal of Environmental Management* 90:1476-1482.

Long, J.S., and J. Freese. 2014. *Regression Models for Categorical Dependent Variables Using Stata.* 3rd Edition ed. College Station, TX: Stata Press.

McConnell, K.E. 1997. "Income and the demand for environmental quality." *Environment and development Economics* 2:383-399.

McCullagh, P. 1980. "Regression models for ordinal data." *Journal of the royal statistical society.* Series B (Methodological):109-142.

McFadden, D. 1973. *Conditional logit analysis of qualitative choice behavior.*

McKelvey, R.D., and W. Zavoina. 1975. "A statistical model for the analysis of ordinal level dependent variables." *Journal of mathematical sociology* 4:103-120.

Mohai, P. 1992. "Men, women, and the environment: An examination of the gender gap in environmental concern and activism." *Society & Natural Resources* 5:1-19.

Murad, H., et al. 2003. "Small Samples and Ordered Logistic Regression." *The American Statistician* 57:155-160.

Papke, L.E., and J.M. Wooldridge. 2008. "Panel data methods for fractional response variables with an application to test pass rates." *Journal of Econometrics* 145:121-133.

Persson, M., E. Sabelström, and B. Gunnarsson. 2009. "Handling of unused prescription drugs—knowledge, behaviour and attitude among Swedish people." *Environment International* 35:771-774.

Peterson, B., and F. Harrell. 1988 *"Partial proportional odds models and the LOGIST procedure."* In SAS Users Group International, thirteenth annual conference, Orlando FL.

Rajecki, D. 1982. *Attitudes: themes and advances*. 1st ed, Inauer Associates, Sunderland, MA.

Rheinisch-Westfaelisches Institut für Wasser (IWW). *"Pharmaceuticals in the environment: Occurence, effects, and options for action. ."* In. Mulheim, Germany, Gernab Federak Environmental Agency (UBA). Available online: https://www.pharmaceuticals-in-the-environment.org/

Saphores, J.-D.M., Nixon, H., Ogunseitan, O.A., and Shapiro, A.A. 2006. "Household willingness to recycle electronic waste an application to California." *Environment and behavior* 38:183-208.

Sønderskov, K.M., and C. Daugbjerg. 2011. "The state and consumer confidence in eco-labeling: organic labeling in Denmark, Sweden, The United Kingdom and The United States." *Agriculture and Human Values* 28:507-517.

Stern, P.C., T. Dietz, and L. Kalof. 1993. "Value orientations, gender, and environmental concern." *Environment and behavior* 25:322-348.

Strategic Approach to International Chemicals Management (SAICM). 2015. *Nomination for new emerging policy issue: environmentally persistent pharmaceutical pollutants.* Geneva: 2015. International Conference on Chemicals Management.

Teisl, M.F., and K. O'Brien. 2003. "Who cares and who acts? Outdoor recreationists exhibit different levels of environmental concern and behavior." *Environment and behavior* 35:506-522.

Tong, A.Y., B.M. Peake, and R. Braund. 2011. "Disposal practices for unused medications around the world." *Environment International* 37:292-298.

Torgler, B., M.A. Garcia-Valiñas, and A. Macintyre. 2008. "Differences in preferences towards the environment: the Impact of a gender, age and parental effect." *FEEM Working Paper* No. 18.

U.S. Census Bureau. 2014. "*2010-2014 American Community Survey 5-Year Estimates.*" U.S. Department of Commerce. Available online: https://www.census.gov/

Vajda, A.M., Barber, L.B, Gray, J.L., Lopez, E.M., Woodling, J.D. and Norris, D.O. 2008. "Reproductive Disruption in Fish Downstream from an Estrogenic Wastewater Effluent." *Environ. Sci. Technol*. 42:3407-3414.

Vicente-Molina, M.A., A. Fernández-Sáinz, and J. Izagirre-Olaizola. 2013. "Environmental knowledge and other variables affecting pro-environmental behaviour: comparison of university students from emerging and advanced countries." *Journal of Cleaner Production* 61:130-138.

CHAPTER 4. WILLINGNESS TO PAY FOR AN UNWANTED MEDICINE COLLECTION PROGRAM: A DOUBLE HURDLE APPORACH

4.1 Introduction

A number of states and counties across the U.S. have implemented medicine take-back programs to mitigate the environmental problems of improper pharmaceutical disposal and public health risks of accumulation of medicines in households. Pharmaceutical take-back programs have been established in different areas, including permanent locations in police departments, pharmacies, hospitals and other health care facilities, special single and multi-day collection events, and mail programs. Several studies have examined the underlying reasons for pharmaceutical accumulation in households, household pharmaceutical disposal practices, the perception among users and non-users of pharmaceuticals programs, and the willingness to pay for collection programs. However, only a limited number of studies have estimated the social benefits of such programs, and there is no such study in the Great Lakes region. This research examines unwanted medication collection programs in the Great Lakes region with the intent of closing the knowledge gap and provides information on the program's value to policymakers, researchers and program providers.

4.1.1 Literature Review

Pharmaceuticals have been used for thousands of years to treat illnesses and diseases. The U.S. has the highest consumption and expenditure of these chemical components (WHO, 2012). Over the last two decades, stakeholders have wondered about the environmental effects of medicines found in surface and groundwater. Some studies have found detrimental effects in wildlife and ecosystem, even at very low concentrations (Hinck, et al., 2008, Vajda, et al., 2008). Active pharmaceutical ingredients (APIs) enter the environment as a result of excretion from humans, pets and livestock, waste waters from the pharmaceuticals industry, and improper disposal of unused and unwanted prescriptions. Excretion is the most frequent pathway, but in trace concentrations. Flushing medications down the toilet or sink results in high levels of unaltered APIs entering the sewage system and eventually ending up in groundwater. In addition to environmental pollution, unwanted and unused pharmaceutical products at home present a risk for accidental poisoning of children and pets and drug abuse. Prescription drug abuse is a serious public health issue in the country, being the most commonly abused substance leading to death from overdose, even ahead of heroin (NCHS, 2014).

There are several studies on the underlying causes resulting from pharmaceuticals. Some of the topics assessed include the reasons behind pharmaceutical accumulation. The most common reported reasons include recovery from illness, side effects, forgetfulness, death of the patient, automatic refills and over-prescription by physicians (Law, et al., 2015, Ruhoy and Daughton, 2008, Seehusen and Edwards, 2006). The most common disposal practice is the garbage, followed by flushing down the toilet and pouring down the sink. An estimated 10-15% takes their medications to a collection center for proper disposal. It is more likely for individuals that are more environmentally conscious to follow this behavior (Bound, et al., 2006, Glassmeyer, et al., 2009, Kotchen, et al., 2009, Kuspis and Krenzelok, 1996, Musson, et al., 2007, Seehusen and Edwards, 2006, Thach, et al., 2013).

Regarding pharmaceutical take-back programs, a few of the studies have looked at the perception of these programs among users and non-users. Thach et al. (2013) suggest both users and non-users view such programs as a potentially valuable service. About half of the respondents expressed their willingness to pay on a per weight basis. Other studies have evaluated participation rates and the most common medications returned in pilot programs. (Lystlund, et al., 2014, Perry, et al., 2014). One study in California estimated the mean willingness to pay for the establishment of a program in the county (Kotchen, et al., 2009).

These studies have provided useful information that has helped to understand behavior and practices towards prescriptions medications in the U.S. Program providers and policymakers have been able to benefit from the research results to improve awareness throughout the community and concentrate efforts on specific issues. However, it is not possible to extrapolate the results and draw regional or national conclusions, since the sample size for most of these studies is very small, and usually not random.

A number of states and counties across the U.S. have implemented programs to mitigate the environmental problems and public health risks of pharmaceuticals. In the Great Lakes region, some examples of these programs include the Yellow Jug Old Drugs in Michigan, Wisconsin, Illinois and Indiana; Medicine Cabinet Clean-Out Days in Minnesota; and other programs supported by the Illinois-Indiana Sea Grant in police departments mainly across Illinois and Indiana, as well as the Prescription Pill Drug Disposal Program (P_2D_2). A common question among program providers and policymakers is the estimated monetary value of the economic benefits provided to society by these programs. To our knowledge only one study has estimated the mean willingness to pay (WTP) for the implementation of a medicine take-back scheme in a community in Santa Barbara, California.

The contingent valuation (CV) method (Mitchell and Carson, 1989) has been commonly used to estimate the economic value of non-market goods. It is a methodology used to estimate the monetary value of environmental services such as basic life support functions of the ecosystems, wilderness experiences, appreciating wildlife, recreation in lakes and rivers, and knowledge of a species existence. The two main fields of application are the economic valuation of environmental projects to improve environmental quality and to assess the damage from environmental deterioration. If the value of these activities and positive externalities were assessed through their market value, most likely their benefit would be zero. Not considering the non-use value would give wrong signals to policymakers.

The CV method is based on asking people through a survey about their preferences towards a specific good or service. To do so, the research needs to create, through a questionnaire, a hypothetical market where the good or service in question can be traded. The "contingent" component arises because the individuals are then asked to state their preferences, contingent on that specific hypothetical market and the description of the environmental service. The theory assumes that the stated willingness to pay or willingness to accept (WTA), depending on the method employed, are related to the respondents' underlying preferences. Both concepts derive from the Hicksian welfare measure of compensating variation and equivalent variation. Preferences are consistent with the utility maximization principle.

The problem with CV and its major criticism is the fact that it is based on asking people about their possible behavior, rather than observing their actual behavior, as “revealed preference” methods do. Researchers argue that the stated preferences may overestimate their real preferences. This is because the way individuals make a hypothetical decision is fundamentally different from making an actual decision. Furthermore, a number of biases can arise if there is a disconnection between the hypothetical market the researcher intends to portray and the market the consumer bases his answer on.

Stated preferences methods include WTP and WTA. Willingness to pay is the maximum amount an individual is willing to sacrifice for a good or service they view desirable or avoid something undesirable. In contrast, willingness to accept is the minimum amount a person is willing to accept to let go of a good or give approval for a negative externality (Boardman, et al., 2006). Even though in theory the valuation of a good should be the same regardless of the method use, in practice this has not been the reality. WTA have been found to significantly exceed WTP (Coombs, et al., 1967, DellaVigna, 2007, Hammack and Brown, 1974, Hanemann, 1999, Kahneman, et al., 1990, Knetsch, 1990, Lienhoop and MacMillan, 2007, Randall and Stoll, 1980). Several explanations have been proposed, including the lack of income constraints, commitment costs, moral property rights, and human psychology towards getting rid of a good versus receiving (Boyce, et al., 1992, Hoffman and Spitzer, 1993, Kahneman, et al., 1991, Knetsch, 1995, Lin, et al., 2006).

It is for this reason that WTP has been most widely used for the valuation of environmental programs.

The use of a dichotomous format in CV was first incorporated by Bishop and Heberlein (1979). The discrete choice attempts to identify if an individual's underlying value is higher or lower than the stated amount. The general structure for these surveys is a take-it-or-leave-it offer, also known as the elicitation format. The bidding game follows up on the response with either a higher or lower bid amount (depending on the first answer), until their decision changes from yes to no (or no to yes). Similar formats include the spike model and the one-and-one-half-bounded. The closed-ended format is preferred among a number of researchers because of the simplification of the thinking process of respondents (Mitchell and Carson, 1989). The mean value is estimated by comparing the bid amounts and the respondent's underlying value. Some of the discrete choice models that have been employed include probit, binomial, multinomial, nested and mixed logit, and Tobit or censored regression.

During the 90's an interest in recycling as a way to reduce municipal solid waste disposal led to a number of benefit-cost analysis to assess possible policy options. The estimation of the benefits of the implementation of curbside recycling programs, drop-off, recycling locations, automated systems, and electronic waste have all recurred to WTP as a valuation method. All these studies used some kind of dichotomous-choice survey format (Aadland and Caplan, 2003, Camacho-Cuena, et al., 2004, Jamelske and Kipperberg, 2006, Lake, et al., 1996, Tiller, et al., 1997).

The cost of using dichotomous format in surveys is the loss of efficiency. The use of an open-ended format allows for the collection of more information and obtains the respondent's maximum WTP. However, a common problem when using and list of bids and open-ended question is the frequency of zero WTP reported, resulting in observations clustered around the zero value. This characteristic of the dataset requires a censored or truncated econometric approach to avoid biases and inconsistent estimates of the parameters (Tobin, 1958).

These models do not allow a variation in the factors affecting whether or not respondents' participant in the hypothetical market, versus the factors that affect the stated amount that they are willing to pay. A double-hurdle by Cragg (1971) approach allows a variable to be excluded from one of the two decision processes, and has been used to estimate the mean WTP for different pro-environmental behaviors. These studies have taken into consideration data clustering around zero WTP, and allowing for factors that determine participation and consumption to vary (del Saz-Salazar and Rausell-Köster, 2008, Lera-López, et al., 2012, Martínez-Espiñeira, 2006, Moon, et al., 2002, Zorić and Hrovatin, 2012).

Kotchen, et al. (2009) analyzed the willingness to pay for the establishment of a pharmaceutical program in Santa Barbara, California. An assessment through contingent valuation concluded individuals are willing to pay, on average, a premium of $1.53 on each prescription bought to fund a pharmacy disposal program. The estimated total annual benefit for the U.S. was $2.9 billion dollars. The problem of generalizing the findings from this study to the Great Lakes region is the possible biases that could arise as the result of the difference between the representative samples, the number of take-back programs available in the region, the potential costs of environmental pollution in the surface waters, and the realistic realization of the hypothetical case scenario used for contingent valuation in the region.

4.1.2 Objectives

The specific objectives of this study are to:

a) Analyze individual's choice process with respect to willingness to pay for a pharmaceutical take-back program in the Great Lakes region.

b) Assess the determinants of individual's WTP for a medicine collection program.

c) Estimate the mean value of a pharmaceutical collection program in the Great Lakes region.

4.1.3 Hypothesis

The WTP for a medicine collection program is a two-step decision program. First, a decision is made if they are willing to pay for such a program. If they are willing to pay, then the second decision is how much, either per prescription or per visit. The decision process is influenced by the individual's environmental awareness, presence of pharmaceuticals in their home, and socioeconomic characteristics.

- Presence of unwanted pharmaceuticals in the household over the past 12 months has a positive correlation with WTP for a medicine take-back program.
- Higher environmental awareness has a positive correlation with WTP for a medicine take-back program.
- Higher education will have a positive correlation with WTP for a take-back medicine program.

- Individuals with a higher income are more willing to pay for a medicine take-back program. The amount an individual is willing to pay for an unwanted pharmaceutical program will be determined by their purchasing power.

4.2 Data and Methods

4.2.1 Data

To analyze the individual's choice regarding their willingness to pay for medicine take-back programs, the responses from an online 23-question survey was used. The survey was designed to gather information regarding presence of unwanted pharmaceuticals within the household, general medicine disposal practices, likelihood to participate in a medication take-back program, willingness to pay for a medicine disposal program (per prescription and per visit), importance of the environment, and a number of demographic variables from individuals at least 18 years of age. The survey covered households living in Indiana, Illinois, Michigan, Minnesota, Ohio and Wisconsin. The survey was administered by Qualtrics during the summer of 2015. The complete survey instrument can be found in Appendix A.

The sample population was randomly selected, and considered both current and potential participants of take-back medication programs. A total of 2,443 people started the survey. Out of this, 67 were younger than the target population, 15 lived outside the delimited geographical area, and 330 did not complete the survey. This resulted in a total number of respondents of 2,031, from which 378 had previously participated in a medicine take-back program. For this analysis, 1284 observations were considered since 747 observations had missing data.

The survey participants were asked to establish their willingness to pay per prescription (WTPP) and willingness to pay per visit (WTPV). The contingent valuation question was designed assuming a fee had to be paid to drop medications, based on either the number of prescriptions or the number of visits. It is important to mention that currently, all programs are free and there is no actual policy recommendation to charge a participation fee. The hypothetical state was established in the following way:

> “The presence of pharmaceuticals in surface waters is a growing concern. Let’s suppose local authorities are to charge a fee for take-back pharmaceutical programs at local permanent collection sites (e.g. pharmacies, hospitals, other health care centers, police departments, and hazardous waste centers) to address this concern.”

Subsequently, respondents were asked about their willingness to participate, average number of prescriptions likely to dispose-off, and WTP based on the number of prescriptions and per visit. Given the limitations of the survey to ensure a response to these questions, ranges were provided for respondents, instead of allowing for an open question. The options provided for WTPP ranged from $0.00 to $3.00, with $1 dollar increments, and $0.00 to $6.00 with $2 dollar increments for the per visit option. About 60 % of respondents indicated they were not willing to pay to drop off their medications. Approximately 20% expressed their willingness to pay up to $1.00 per prescription and 21% to pay up to $2.00 per visit to drop off unwanted pharmaceuticals. On the average, 8% said they would pay around $1.01-$2.00 per prescription, and 9% $2.01-$4.00 per visit. Fewer people (7%) admitted to being willing to pay about $2.01-$3.00 per prescription and

$4.01-$6.00 per visit. Only 4% expressed their willingness to pay more than $3.00 per prescription, and 3% more than $6.00 per visit. Table 4.1 summarizes the percentage of individual's willingness to pay per prescription and Table 4.2 their willingness to pay per visit. Consistent with economic theory, the trend is that at a higher price, consumers are less willing to pay to take their unwanted medicines to a permanent collection center.

Table 4.1: Distribution of Responses for Willingness to Pay per Prescription

WTTP [USD]	Frequency [%]
$0.00	60.89
$0.01-$1.00	19.83
$1.01-$2.00	8.43
$2.01-$3.00	6.71
$3.01+	4.14

Table 4.2: Distribution of Responses for Willingness to Pay per Visit

WTTV [USD]	Frequency [%]
$0.00	59.64
$0.01-$2.00	21.23
$2.01-$4.00	9.21
$4.01-$6.00	7.26
$6.01+	2.65

All respondents were also asked about their likelihood to participate in a take-back medicine program in the future, before stating a hypothetical state regarding their willingness to pay to participate in the program. This question helped us identify those persons that consider the program valuable enough to participate, but were unwilling to pay for it. Eighteen percent reported they were not likely to participate in such programs in the following 12 months. About 26% of the sample population was uncertain, having reported they are neither likely nor unlikely to become participants. About half (56%) of the survey respondents indicated they were likely to use a pharmaceutical collection program in the coming year. However, when asked about their willingness to participate in the hypothetical scenario that charges a fee to use the program, only 36% responded they were willing to participate, and 12% reported they were neither willing nor unwilling. Half of the households (51%) were unwilling to drop off their medications in a permanent location if a fee was implemented.

As shown in Table 4.3, 26.72 % of the sample population stated they are likely to participate in a medicine collection program within the next month, and they would be willing to participate even if a fee had to be paid for every prescription dropped-off or every time they used the program. An estimate of 24% of individuals stated they would be likely to dispose of their unwanted medications through a program, but when asked if they would be willing to participate with a fee in place they said no. This observation suggests there is a number of individuals that consider the benefit of the program is greater than the opportunity cost of participating, as long as no other fees are in place.

Table 4.3: Percentage of Likelihood of Participation and Willingness to Participate in a Medicine Take-Back Program.

Variable [%]	Unlikely	Neutral	Likely	Total
Unwilling	12.97	14.69	23.52	51.17
Neutral	2.34	4.61	5.47	12.42
Willing	2.81	6.88	26.72	36.41
Total	18.13	26.17	55.70	100.00

The variables that were considered relevant as the determinants of WTP included environmental practices of the household (***Env***), pharmaceutical related variables (***Phar***), and demographic variables (***Dem***).

Environmental Practices (***Env***)

Pharmaceutical collection programs have a positive effect on the environment. The environmental variables included environmental awareness and the number of environmental programs households are engaged in. Environmental awareness was measured in the form of importance of environmental quality to the individual, i.e. important (*e.imp*), neutral (*e.ntrl*) and unimportant (*e.unimp*). Only 2% considered the environmental quality as unimportant to them, 15% responded to be neutral, and 84% claimed the environmental quality as an important factor. The importance of the environment was assumed to affect only the first step in the decision process, i.e. whether or not they are WTP for a collection program.

The variable *#envp* was defined as the number of environmentally friendly programs a household participates in which ranged from 0-5. The programs considered included recycling, composting, water conservation, energy conservation, and use of environmentally friendly products. Only 2% responded they are currently not involved in any of these practices. Nineteen percent of the sampled population participates in one of these activities, 19% of the households are engaged in two of these programs, 24% in three programs, 27% in four programs, and 9% in all five activities. The most practiced activity is recycling, followed by energy conservation practices and water conservation practices. The expectation was that the number of environmental programs household are engaged in, will not only determine willingness to pay (step 1), but it would also affect how much households are willing to pay (step 2).

Unwanted Pharmaceuticals (***Phar***)

The presence of unwanted pharmaceutical in the household over the last 12 months (*unmed*) may influence their WTP. About 25% of the individuals did not have unused or unwanted pharmaceuticals, and 75% did have. Respondents were also asked about the number of prescriptions (*#Rx*) they would be likely to drop off at a collection point in the future. The response was included as a reference to the potential amount of prescriptions within the household, which on average was 2.03. These two variables were included in the model to help explain the participation behavior based on the existence of unwanted pharmaceuticals in a household. It is presumed that these variables would have a positive effect on the WTP per prescription and WTP per visit. Intuition suggests that the presence of unwanted medications in a household will determine if they would be willing to pay, but not how much, while the number of prescriptions the household is likely to dispose of may have a negative effect on the level of participation, i.e. how much they are willing to pay.

A dummy variable was also added to capture respondents that have participated in a medicine collection program before (*part*). About 350 people have previously participated either in a permanent collection, single day collection program, or mailed back their medicines. The expectation is that this variable will have a positive impact on WTP for such programs.

Socio-economic Variables (***Dem***)

The demographic factors included average household income, number of people in the household, college education, age and gender. The five categories for average annual household income were defined as: $0.00-$30,000 (*inc0*), $30,001-$45,000 (*inc30*), $45,001-$60,000 (*inc45*), $60,001-$75,000 (*inc60*), and over $75,000 (*inc75*). In Table 4.4, the percentage of individuals from each income level for each expressed willingness to pay is shown. Interestingly, 53% of the individuals that expressed WTPP zero, had an annual household income corresponding to either tail of the distribution (*inc0* or *inc75+*). In line with the literature, we observe a trend of the percentage of people from lower income groups decreasing for each bid amount, but the number of individuals from higher income level increases with bid amounts. The same behavior was observed when comparing income with willingness to pay per visit. It is expected that households with a higher income will have a higher willingness to pay both per prescription and per visit because they have more disposable income, assuming all other variables are constant.

Table 4.4: Proportion of Individual's WTPP Given Annual Household Income

		Willingness to Pay per Prescription [USD]					
	Variable [%]	$0.00	$0.01-$1.00	$1.01-$2.00	$2.01-$3.00	$3.00+	Total
Annual Household Income [MUSD]	$0-$30	29.36	24.80	16.67	10.47	18.87	25.68
	$30.01-$45	18.59	19.29	15.74	11.63	5.66	17.49
	$45.01-$60	17.05	17.32	18.52	15.12	5.66	16.63
	$60.01-$75	11.28	12.60	16.67	31.40	11.32	13.35
	$75.01+	23.72	25.98	32.41	31.40	58.49	26.85

The average size of the households is 2-3 persons. The number of people in a household (*#pple*) presumes that with more members in a family, the number of unwanted pharmaceuticals in a house might be higher. Therefore, the risk of accidental or intentional abuse of the medicines can increase. For this reasons, it is expected that the number of people in a household will have a positive effect on WTP.

Education, age and gender do not define households as a whole but they do provide some information regarding the potential use of pharmaceutical take-back programs. To control for the level of education, a dummy variable to describe those individuals with a college degree or higher (*edu*) was included. Sixty-seven percent of our sample population has at least a college degree, while for 33%, their highest level of completed education is high-school. Education may have a positive impact on environmental awareness, and can then affect the decision of an individual regarding properly disposal of their medications.

The age groups considered for our analysis were 18-45 years old (*age18*), 46-65 years old (*age46*), and over 65 years old (*age65*). The literature suggests a negative correlation between age and environmentally friendly practices (Kotchen, et al., 2009, Torgler, et al., 2008). The same relationship is observed in the data, as shown in Table 4.5. The percentage of individuals from the first age group (*age18*) increases as consumers are willing to pay a higher amount. In other words, the proportion of young adults in relation to other age groups increases as the bid amount goes up. The inverse relationship is observed for older citizens. The presumption is that as people grow old, the number of prescriptions in their homes increase, therefore age has a negative effect on how much a person would be willing to pay to drop off their medications. This is logical because economic theory indicates quantity has an inverse relationship with price.

Table 4.5: Proportion of Individual's WTPP Given Age Group

		Willingness to Pay per Prescription [USD]					
Age [years old]	Variable [%]	$0.00	$0.01-$1.00	$1.01-$2.00	$2.01-$3.00	$3.00+	Total
	18-45	45.38	47.24	71.30	87.21	84.91	52.38
	46-65	37.82	34.32	21.30	9.30	11.32	32.71
	65+	16.79	18.50	7.41	3.49	3.77	14.91

For gender (*male*), the expectancy following other studies is that women have a stronger preference to participate in environmental programs than men, and as such would be willing to pay more (Ferreira and Moro, 2013, Kotchen, et al., 2009).

4.2.2 Methodology: Censored Regression Models

A significant number of respondents, accounting for 60% of the sample population, reported zero WTP (both per prescription and per visit). Tobin (1958) was the first to propose a censored regression model, the Tobit model, to analyze such data with significant zero observations. The model has been used to analyze consumption patterns and behavior from household or individual surveys where a significant number of respondents report zero consumption. The Tobit model is defined as:

$$y_i^* = \boldsymbol{x_i'\beta} + \varepsilon_i,\ \varepsilon_i \sim N(0, \sigma^2), \tag{5.1}$$

with a censoring rule such that:

$$\begin{aligned} y_i &= 0 \text{ if } y_i^* \leq 0 \\ y_i &= y_i^* \text{ if } y_i^* > 0 \end{aligned} \tag{5.2}$$

where y_i^*represents the desired contribution of subject i, β is a vector of exogenous variables, and y_i is the observed contribution.

The likelihood function is given by:

$$f(y|x_i) = \left\{1 - \Phi\left(\frac{x_i\beta}{\sigma}\right)\right\}^{1(y=0)} \left[(2\pi)^{\frac{-1}{2}}\sigma^{-1} exp\left\{\frac{-(y-x_i\beta)^2}{2\sigma^2}\right\}\right]^{1(y>0)} \tag{5. 3}$$

where Φ is the standard normal cumulative distribution function and 1(y=0) and 1(y>0) are the exponential indicator functions.

For the purpose of the analysis, the empirical Tobit model was defined as:

$$y_i^* = \boldsymbol{Env_i\beta_{Env}} + \boldsymbol{Phar_i\beta_{Phar}} + \boldsymbol{Dem_i\beta_{Dem}} + \varepsilon_i,\ \ i = 1, \dots, n. \tag{5.4}$$

where $\boldsymbol{Env_i}$ is the vector set of independent environmental variables including *e.imp, e.ntrl* and *#envp;* $\boldsymbol{Phar}$ is the vector set of pharmaceutical related variables including *unmed, part* and *#Rx;* $\boldsymbol{Dem}$ is the vector set of socioeconomic variables including *#pple, inc30, inc45, inc60, inc75, edu, age18, age46,* and *male.* Two different models with different dependent variables (y_i^*) were estimated, *WTPP* and *WTPV*. In the Tobit model, given its parametrization, the factors that determine the probability of consumption are the same factors that affect the level of consumption.

Cragg (1971) proposed a more general and flexible model where the decision of participation and the level of consumption (amount willing to pay) are determined by two different stochastic processes. This model considers the possibility that factors influencing willingness to pay and factors influencing the amount paid may be different. The maximum likelihood estimator in the first hurdle can be obtained using a Probit estimator, and the second hurdle can be estimated from a truncated normal regression model. The log likelihood function is given by:

$$f(w, y|\boldsymbol{x_1}, \boldsymbol{x_2}) = \{1 - \phi(\boldsymbol{x_i}\gamma)\}^{1(w=0)} \left[\phi(\boldsymbol{x_1}\gamma)(2\pi)^{\frac{-1}{2}}\sigma^{-1}\, exp\left\{\frac{-(y - x_2\beta)^2}{2\sigma^2}\right\}/\phi\left(\boldsymbol{x_2}\,{}^{\beta}/_{\sigma}\right)\right]^{1(w-1)} \quad (5.5)$$

where *w* is a binary indicator equal to 1 if *y*>0 and 0 otherwise, and $\boldsymbol{\gamma}$ and $\boldsymbol{\beta}$ are different vectors that determine participation and consumption. This model was estimated using Stata 13.1 with Burke's (2009) estimation command *craggit*.

In the Double Hurdle (DH) Model, the estimation vector for each stage consisted of different variables. Just as with the Tobit model, the DH model was estimated twice with *WTPP* and *WTPV* as the dependent variables. The first stage for the probit estimation was defined as:

$$y_{i,1st}^* = \boldsymbol{Env_i\beta_{Env}} + \boldsymbol{Phar_i\beta_{Phar}} + \boldsymbol{Dem_i\beta_{Dem}} + \varepsilon_i, \quad i = 1, \dots, n. \quad (5.6)$$

where $\boldsymbol{Env_i}$ is the vector set of independent environmental variables including *e.imp, e.ntrl* and *#envp;* $\boldsymbol{Phar_i}$ is the vector set of pharmaceutical related variables including *unmed,* *part* and *#Rx;* $\boldsymbol{Dem_i}$ is the vector set of socioeconomic variables including *#pple*, *inc30*, *inc45*, *inc60*, *inc75*, *edu*,*age18*,*age46*, and *male*.

For the second stage, the variables related to the level (how much) of willingness to pay were:

$$y^*_{i,2nd} = \boldsymbol{Env_{(res)i}\beta_{Env}} + \boldsymbol{Phar_{(res)i}\beta_{Phar}} + \boldsymbol{Dem_i\beta_{Dem}} + \varepsilon_i, \quad i = 1, \dots, n. \qquad (5.7)$$

where the only environmental variable included in $\boldsymbol{Env_{(res)i}}$ is *#envp*, $\boldsymbol{Phar_{(res)i}}$ includes *part* and *#Rx* and $\boldsymbol{Dem_i}$ which includes the same variables as the first stage. Initially, the respective states were included as variables (*Geo*$_i$) in the model. However, further analysis suggested an over specification given a non-statistical T-student nor joint significance. To test this hypothesis, an F-test was used, with H_0: $\boldsymbol{\beta_{Geo}} = 0$ and H_a: $\boldsymbol{\beta_{Geo}} \neq 0$. The results were χ^2 of 12.36 with Prob>chi2 of 0.26 for the WTP per prescription; and χ^2 of 13.73 with Prob>chi2 of 0.18 for WTP per visit models. We therefore fail to reject the null hypothesis that the model supports the imposed restriction of $\boldsymbol{\beta_{Geo}} = 0$.

The estimations obtained by both models facilitate the calculation of the probability that *y*=0, $P(y_i = 0|x_{1i})$ and the probability that *y*>0, $P(y_i > 0|x_{1i})$. From Cragg's model, the probabilities are calculated as:

$$P(y_i = 0|x_{1i}) = 1 - \Phi(x_{1i}\gamma) \qquad (5.8)$$

$$P(y_i > 0|x_{1i}) = \Phi(x_{1i}\gamma) \qquad (5.9)$$

Given these probabilities, the expected value of *y* can be estimated, given *x* and that y_i>0, $E(y_i|y_i > 0, x_{2i})$ and the unconditional expected value, $E(y_i|x_{2i})$ the following way:

$$E(y_i|y_i > 0, x_{2i}) = x_{2i}\beta + \sigma \times \lambda(x_{2i}\,\beta/\sigma) \qquad (5.10)$$

$$E(y_i|x_{1i}, x_{2i}) = \Phi(x_{1i}\gamma)\{x_{2i}\beta + \sigma \times \lambda(x_{2i}\,\beta/\sigma)\} \qquad (5.11)$$

with $\lambda(c)$ as the inverse Mills ratio $\lambda(c) = \phi(c)/\Phi(c)$ where $\phi(c)$ is the standard normal probability distribution function. From the estimated mean willingness to pay per prescription and per visit, the total annual benefits of an unwanted pharmaceuticals program were estimated.

4.3 Results and Discussion

4.3.1 Unwanted Medicine Behavior and Disposal Practices

In addition to the willingness to pay per prescription and per visit, the survey responses provided information about the reasons for pharmaceuticals accumulation and disposal practices. An estimated 61% of the households that participated in the survey have had unwanted pharmaceuticals in their home over the past 12 month. The main reasons for the accumulation of these substances are: users stopped taking the medication before the supply ran out (33%), not knowing what to do with the expired medicines (32%), and a change in medication (25%).

Regarding disposal practices, about 68% of respondents reported they had disposed of unwanted pharmaceuticals at some point in the past. In line with other studies (Kotchen, et al., 2009, Kuspis and Krenzelok, 1996), the most common disposal method reported is throwing the substances in the trash (44%), followed by flushing them down the toiler or sink (29 %). Most people dispose the pharmaceuticals of their own households, while a few report doing so for other relatives or their pets.

A total of 378 persons reported they have participated in some kind of take-back program in the past. These programs include single day collection programs, mail back programs, and permanent collection boxes at pharmacies, police departments, hospitals and other health care centers. Three out of 4 users have participated only in one type of program, while 25% have used at least two different types of collection centers. The most popular types of programs are the single-day collection events, followed by the permanent collection boxes at police departments and pharmacies. Mail programs are the least popular, accounting only for 7% of the participation rates. On average, users have been participating for 19 months in these programs, and they travel an average of 12.5 miles to dispose 5-6 different types of prescriptions.

4.3.2 Double Hurdle Model

The estimation of the participant's willingness to pay per prescription for the Tobit and Double Hurdle model are summarized in Table 4.6 and WTP per visit in Table 4.7. The Tobit model is nested within Cragg's alternative because when $\boldsymbol{x_1} = \boldsymbol{x_2}$ and $\gamma = {}^{\beta}/_{\sigma}$, the models are identical. To assess which is the most appropriate specification, there is a need to determine if the individual's decision on the extent of participation (WTP) is the result of a step-wise decision or not. The first decision would consist of determining whether the individual would be willing to pay, and the second is the amount they would be willing to pay, given that the individual is willing to pay. If this is the case, a Double Hurdle model would be the most appropriate approach. Otherwise, if no evidence indicates a step-wise decision, a more general Tobit model would suffice. A log-likelihood test was used to determine which model is the most appropriate for the data. The results are a χ^2 of 53.72 for WTP per prescription and χ^2 of 41.81 for the WTP per visit, therefore the null hypothesis that the decision process is only a one step process is rejected. That means the DH is the most appropriate specification for the study.

The importance of determining the correct model can be appreciated when comparing the independent variables that determine participation in each case. From Table 4.6, the Tobit model results show that environmental importance (*e.imp*) and at least a college education (*edu*) affect WTP and the amount WTP at a significance level of 10 %. Previous participation in a take back medicine program (*part*) and gender (*male*) are significant at a 5 % level; while number of prescriptions likely to dispose of *(#Rx*), average annual household income above $60,000 dollars (*inc60* and *inc75*), and age 18-45 years old (*age18*) are significant at a 1% level. Similar results are found for the Tobit model determining WTPV in Table 4.7. The difference between these estimations is the statistical significance level of having had unwanted medications in the household over the past 12 months (*unmed*) and the lack of significance of the gender (*male.*)

The results from the Double Hurdle model are also presented in Tables 4.6 and 4.7 respectively for WTP per prescription and for willingness to pay per visit. From Table 4.6, the decision of WTPP is determined by the number of prescriptions likely to dispose of (*#Rx*), the presence of unwanted pharmaceuticals in the household (*unmed*), annual household income between $60,000 -$75,000 (*inc60*), annual household income above $75,000 (*inc75*), age (*yrs18*), and the number of people living in a household (*#pple*).

The factors that determine the level of consumption are the number of environmental programs households are involved in (*#envp*), the number of prescriptions that consumers would get rid of (*#Rx*), age (*age18*), gender (*male*), and income level (*inc60* and *inc75*). Thus, we can conclude that the factors that influence a person's decision to participate in a paid pharmaceutical collection program are different from the factors that determine how much they are willing to pay per prescription. A similar observation applies when individuals are asked for their willingness to pay per visit, as observed in Table 4.7. The only difference is the independent variables that influence the decision process.

Environmental Practices ***(Env)***

The amount consumers are willing to pay per prescriptions (Table 4.6) is influenced by the number of environmental programs the household is engaged in (*#envp*). Pro-environmental behavior is associated with higher environmental awareness, thus the expectation was a positive effect on how much individuals are willing to pay for a drug collection program. However, the results suggest participation in other environmental program has a negative effect on the consumption level of individuals. The possible explanation to this finding is that, if participation in other environmental programs involves additional costs (e.g. higher price, participation fees, and transportation time), then the more programs a family is enrolled in, the amount of disposable income left that the household is willing to spend on other environment programs is lower. Furthermore, individuals may consider the program to have a positive benefit, but the marginal benefits perceived from this specific program in contrast with another environmental programs may be lower. Thus, there may be some trade-off or substitution effect. From Table 4.7, the number of pro-environmental programs is not statistically significant when determining the WTP and the amount WTP per visit.

Table 4.6: WTP per Prescription from Tobit and DHM Estimations.

	Variable	Tobit	Double Hurdle	
		Coefficients	Participation	Consumption
Env	*e.ntrl*	-0.168 (0.480)	-0.084 (0.310)	
	e.imp	0.884* (0.460)	0.465 (0.298)	
	#envp	-0.069 (0.050)	0.012 (0.034)	-0.211*** (0.077)
Phar	*part*	0.296** (0.127)	0.127 (0.086)	0.312 (0.192)
	unmed	0.174 (0.140)	0.185** (0.091)	
	#Rx	0.150*** (0.026)	0.102*** (0.019)	0.060* (0.032)
Dem	*#pple*	-0.050 (0.045)	-0.052* (0.030)	0.051 (0.069)
	inc30	0.169 (0.179)	0.116 (0.116)	0.103 (0.324)
	inc45	0.203 (0.183)	0.122 (0.120)	0.229 (0.315)
	inc60	0.633*** (0.192)	0.343*** (0.129)	0.727** (0.302)
	inc75	0.531*** (0.169)	0.266** (0.111)	0.670** (0.283)
	edu	0.234* (0.128)	0.138 (0.084)	0.007 (0.225)
	age18	0.940*** (0.186)	0.408*** (0.121)	1.662*** (0.393)
	age46	-0.029 (0.187)	-0.071 (0.120)	0.457 (0.397)
	male	0.291** (0.122)	0.075 (0.082)	0.589*** (0.183)
	_cons	-2.412*** (0.510)	-1.438*** (0.327)	-0.971* (0.567)
	sigma_cons	1.666*** (0.059)		1.315*** (0.086)
	N	1,284		1,284

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Table 4.7: WTP per Visit from Tobit and DHM Estimations.

	Variable	Tobit	Double Hurdle	
		Coefficient	Participation	Consumption
Env	*e.ntrl*	-0.626 (0.850)	-0.298 (0.300)	
	e.imp	1.429* (0.810)	0.354 (0.287)	
	#envp	-0.070 (0.090)	0.013 (0.034)	-0.200 (0.132)
Phar	*part*	0.558** (0.228)	0.143* (0.086)	0.485 (0.333)
	unmed	0.646** (0.255)	0.242*** (0.091)	
	#Rx	0.316*** (0.046)	0.111*** (0.020)	0.190*** (0.053)
Dem	*#pple*	-0.107 (0.081)	-0.068** (0.030)	0.177 (0.126)
	inc30	0.255 (0.324)	0.130 (0.116)	-0.268 (0.600)
	inc45	0.523 (0.328)	0.174 (0.120)	0.610 (0.555)
	inc60	1.157*** (0.346)	0.353*** (0.129)	1.371** (0.545)
	inc75	1.121*** (0.306)	0.261** (0.112)	1.765*** (0.514)
	edu	0.451* (0.232)	0.151* (0.084)	0.107 (0.399)
	age18	1.552*** (0.335)	0.434*** (0.122)	2.032*** (0.626)
	age46	-0.095 (0.335)	-0.040 (0.120)	0.186 (0.647)
	male	0.233 (0.219)	0.053 (0.082)	0.227 (0.321)
	_cons	-4.432*** (0.901)	-1.338*** (0.317)	-1.721* (0.964)
	sigma_cons	3.013*** (0.105)		2.382*** (0.149)
	N	1,284	1,284	

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Unwanted Pharmaceuticals ***(Phar)***

An individual's decision of willingness to pay for each prescription (Table 4.6) and per visit to a pharmaceuticals disposal program (Table 4.7) is influenced positively by the number of prescriptions (*#Rx)*. It may be that the number of medicines a person is likely to dispose-off is a reflection of the number of medicines accumulated in their household. Thus, the utility from using the program is higher as the number of prescriptions increases, and the risks related with improper storage such as accidental poisoning and abuse decrease. The same reasoning applies for the effect of whether the household has had unwanted medicines at the home the past 12 months (*unmed*), when determining participation. Perhaps, it may also explain the findings in Table 4.7., i.e., the number of prescriptions (*#Rx)* also has a statistically significant positive effect in the level of consumption for both models.

Socio-economic Variables ***(Dem)***

The expectation was that household size (*#pple*) would have a positive effect on the participation decision in WTP as a result of higher risk of accidental poisoning and drug abuse. However, the results suggest there is a statistically significant negative effect in both models (Table 4.6 for WTPP and Table 4.7 for WTPV). The negative association may result from higher expected expenses in larger households that constraint the proportion of the budget used for pro-environmental activities.

Annual household income is another factor that influences the individual's participation decision positively. The effect is statistically significant at the 1% level for *inc60* and at the 5% for *inc75* (Table 4.6). We also expected the income to be a statistically significant factor when determining the amount consumer would potentially pay (Table

4.7). The model estimations suggest the expectations hold with statistical confidence (5%). The estimated coefficients support findings in the literature of a positive relationship between household income and willingness to pay for an environmental program.

People age 18-45 have a statistical positive correlation (1% confidence level) with the participation and consumption decision process for both models. As alluded earlier, on average, younger adults are more willing to pay for a pharmaceutical collection program. Furthermore, although not statistically significant, we observe a negative correlation between willingness to pay for an environmental program and the older age group.

Studies on environmental program participation have found women are more likely to participate than men. The results from Table 4.7 for WTPV suggest the amount individuals are willing to pay per visit (2nd stage) is influenced, at a statistically significantly level (1 %) by male gender. The difference with previous studies might be explained by the fact that, although women tend to express more environmental concern than men, this does not necessarily imply they are more likely to actually engage in environmental actions compared to men (Blocker and Eckberg, 1997).

To assess the fit of the estimated model, the predicted probabilities of individuals at each hurdle of the model (participation and consumption) were estimated and compared with the data set. The results are summarized in Table 4.8 and Table 4.9. Sixty-four percent of survey respondents were not willing to pay for a medicine collection program, both per prescription and per visit. The model predicts that there is 39% probability of participants willing to pay per prescription and 40% probability of willingness to pay per visit. The model's predicted probability of individual's participation is lower than the observed participation rates of the complete sample population by 3% for WTPP and 4% for WTPV.

Table 4.8: Percentage of Respondents WTPP from Sample vs.
Predicted Probabilities Calculated from DHM.

Model	Variable	Observations	Mean	St. Dev
Observed WTP per Prescription	Unwilling (WTP=0)	2016	0.64	
	Willing (WTP>0)	2016	0.36	0.47
Predicted Probability WTP per prescription	Unwilling (WTP=0)	1287	0.61	0.16
	Unwilling (WTP=0)	1287	0.39	0.16

Table 4.9: Percentage of Respondents WTPV from Sample vs.
Predicted Probabilities Calculated from DHM.

Model	Variable	Observations	Mean	St. Dev
Observed WTP per Visit	Unwilling (WTP=0)	2018	0.64	
	Willing (WTP>0)	2018	0.36	0.48
Predicted Probability WTP per Visit	Unwilling (WTP=0)	1287	0.60	0.17
	Unwilling (WTP=0)	1287	0.40	0.17

Based on the DH model results presented in Table 4.6 and Table 4.7, the mean willingness to pay per prescription and per visit were estimated and are presented in Table 4.10. The estimated unconditional mean willingness to pay per prescription is $0.53 and the mean willingness to pay for those who have a positive willingness to pay per prescription is $1.25 (Table 4.10). In the case of WTP per visit, the mean value for all consumers is $1.03, and $2.33 for those that move on to the second hurdle.

Table 4.10: Estimated Mean WTP from DHM.

Dependent Variable	Conditional WTP	Observations	Mean	St. Dev
WTP per Prescription	WTP E(y|y>0)	1293	$1.25	0.43
	WTP E(y)	1287	$0.53	0.40
WTP per Visit	WTP E(y|y>0)	1293	$2.33	0.80
	WTP E(y)	1287	$1.03	0.78

Table 4.11: Estimated Mean WTP from DHM from Previous Program Participants (*part=1*).

Dependent Variable	Conditional WTP	Mean	St. Dev
WTP per Prescription	WTP E(y|y>0)	$1.40	0.55
	WTP E(y)	$0.72	0.53
WTP per Visit	WTP E(y|y>0)	$2.64	1.01
	WTP E(y)	$1.42	1.03

The mean willingness to pay for only respondents that had previously participated in a medicine take-back were also estimated (Table 4.11). The results suggest that these individuals are willing to pay a slightly higher price per prescription and per visit. For example, the unconditional mean WTP for all respondents per prescription is $0.53 (Table 4.10), while those that have participated in previous program are willing to pay $0.72 per prescription (Table 4.11), $0.17 more. Similarly, the unconditional WTP per visit for all individuals is $1.03 and $1.42 for those that have previously participated in a program; a difference of $0.39. The difference in the mean WTP given a predicted positive participation in the first stage of the model between all individuals and recurrent participants is $0.15 per prescription and $0.31 per visit.

4.3.3 Total Annual Benefits: Homogeneous Population

With the estimated mean willingness to pay for each model, the total annual benefits for a pharmaceutical program were calculated for different assumptions: a) total population in the region; b) number of households in the region; c) previous participation in a take-back program; d) widespread participation. We used the U.S. Census Bureau population and household data from 2013 in the Great Lakes region to estimate mean willingness to pay per prescription and per visit, and the average number of prescriptions likely to dispose reported by respondents. The total population (millions of people) of at least 18 years old per state is as follows: Indiana 5.0; Illinois 9.9; Ohio 8.9; Michigan 7.7; Wisconsin 4.4; Minnesota 4.1. The number of households (millions of households) per state is: Indiana 2.5; Illinois 4.8; Ohio 4.6; Michigan 3.8; Wisconsin 2.3; Minnesota 2.1 (U.S. Bureau, 2014). For the calculation of the annual benefits given the WTP per prescription for the entire sample, the average number of prescriptions used was 2.03 and for those who had previously participated in a program, i.e. *part*=1, 4.65 prescriptions. With these assumptions, we consider the total annual benefits estimated to be a conservative approach, given that the assumptions imply a single participation in the year.

Scenario 1 (per prescription):

First, we estimated the total annual benefits per state given the unconditional mean WTPP ($0.53) based on estimates from the entire sample (Table 4.10) and the total population. The total annual benefits per state are summarized in column (a) of Table 4.12. For the Great Lakes region, the estimated social benefits from pharmaceutical programs are $43 million for the total population. Participants of a medicine collection program usually dispose of the medications from the household. Thus, a more conservative estimation is to consider the total number of households per state. The annual benefits from this estimation total $21.6 million per year, as shown in column (b) Table 4.12.

The econometric model indicated that the estimated unconditional mean WTPP for recurrent participants of pharmaceutical programs is higher than the unconditional average from the entire sample population ($0.53 vs $0.72). The number of prescriptions likely to dispose also varied (2.03 vs 4.65). Thus, we also estimated the annual benefits of a collection program for recurrent participants. We assumed a participation rate of 18%. Under these assumptions, the yearly benefits of drug collection program in the Great Lakes add to $12.5 million (column (c) of Table 4.12). Lastly, a hypothetical scenario assuming awareness campaigns resulted in widespread participation of households was estimated. We assumed the mean WTPP for *part*=1 and 4.65 disposed prescriptions. The value of the program under this scenario is $67.2 million per year (column (d) in Table 4.12).

Table 4.12: Annual Benefits Calculated from WTPP per Scenario. ($Million)

	(a)	(b)	(c)	(d)
State	Total Population	No. Households	Current Participation	Widespread participation
Indiana	$5.4	$2.7	$1.6	$8.3
Illinois	$10.6	$5.1	$3.0	$16.0
Ohio	$9.6	$4.9	$2.8	$15.3
Michigan	$8.2	$4.1	$2.4	$12.8
Wisconsin	$4.8	$2.5	$1.4	$7.7
Minnesota	$4.5	$2.3	$1.3	$7.1
Total	$43.0	$21.6	$12.5	$67.2

Scenario 2 (per visit):

The annual benefits that result from the estimated mean willingness to pay per visit were also estimated. The assumptions made included a single visit per year for the general population, and 2 annual visits for recurring participants. The total annual benefits are summarized in Table 4.13. For a single visit by the entire population, column (a), the total annual benefit is $41.2 million; and considering participation at a household level, the benefit amounts to $20.7 million, column (b). For two visits for recurring participants, the societal value of the program is estimated to be $10.6 million for current participation rates, column (c), and $57.0 assuming widespread participation, column (d). These estimates are very similar to those estimated by the WTP per prescription.

Table 4.13: Annual Benefits Calculated from WTPV and per Scenario ($Million).

State	(a) Total Population	(b) No. Households	(c) Current Participation	(d) Widespread Participation
Indiana	$5.1	$2.6	$1.3	$7.1
Illinois	$10.2	$4.9	$2.5	$13.6
Ohio	$9.2	$4.7	$2.4	$13.0
Michigan	$7.9	$3.9	$2.0	$10.9
Wisconsin	$4.6	$2.4	$1.2	$6.5
Minnesota	$4.3	$2.2	$1.1	$6.0
Total	$41.2	$20.7	$10.61	$57.02

Scenario 3 (per prescription for WTP E(y|y>0):

Next, we estimated the total annual societal value for the proportion of the sample that proceeded to the second hurdle of the model, WTP E(y|y>0). Under these assumption, the benefits of only those willing to pay to participate in a medicine disposal program are considered. Recalling from Table 4.10 and Table 4.11, the average WTPP for this sample of the population is $1.25 and $1.40 for previous participants. Under this assumption, the number of prescriptions and participation rates do not vary. From the model, 39% of the population is expected to have a mean willingness to pay per prescription greater than 0. The estimated total benefits for various assumptions are reported in Table 4.14. The total benefit for the total population is estimated to be $39.6 million while the benefit for the current program participants is $9.5 million. The difference between the benefits estimated using the conditional mean WTP and the unconditional mean WTP are -7.9%, when considering the whole population, and -24.1% when estimating for recurring participants.

Scenario 4 (per visit for WTP E(y|y>0):

The annual benefits estimated with the conditional mean per visit from the second hurdle of the model were also calculated (Table 4.15). In this case, the predicted probability from Table 4.9 of individuals with WTPV>0 is 40%. The mean values for the entire data set is \$2.33 and \$2.64 for *part*=1. The total monetary value is estimated at \$37.3 for the total population, column (a), \$18.7 for the number of households, column (b), \$7.9 for current participants, column (c), and \$42.4 for widespread participation, column (d). Details by state are summarized in Table 4.15. Similarly to the per prescription case, the estimated benefits are lower under these assumptions (-9.5% for *all*, and 25.5% for *part*=1).

Table 4.14: Annual Benefits Calculated from WTPP and WTP>0 per Scenario(\$Million).

State	(a) Total Population	(b) No. Households	(c) Current Participation	(d) Widespread Participation
Indiana	\$4.9	\$2.5	\$1.2	\$6.3
Illinois	\$9.8	\$4.7	\$2.3	\$12.1
Ohio	\$8.8	\$4.5	\$2.2	\$11.6
Michigan	\$7.6	\$3.8	\$1.8	\$9.7
Wisconsin	\$4.4	\$2.3	\$1.1	\$5.8
Minnesota	\$4.1	\$2.1	\$1.0	\$5.4
Total	\$39.6	\$19.9	\$9.5	\$51.0

Table 4.15: Annual Benefits Calculated from WTPV and WTP>0 per Scenario ($Million).

State	(a) Total Population	(b) No. Households	(c) Current Participation	(d) Widespread Participation
Indiana	$4.7	$2.3	$1.0	$5.3
Illinois	$9.2	$4.5	$1.9	$10.1
Ohio	$8.3	$4.3	$1.8	$9.7
Michigan	$7.2	$3.6	$1.5	$8.1
Wisconsin	$4.1	$2.1	$0.9	$4.8
Minnesota	$3.8	$2.0	$0.8	$4.5
Total	$37.3	$18.7	$7.9	$42.4

Average Annual Benefits:

In summary, the results obtained suggest that pharmaceutical collection programs provide a positive value to society in the Great Lakes area. To estimate the value of medicine take-back programs under each assumption (total population, total households, participant households and widespread participation), an average of the total annual benefits estimated from Scenario 1 and 3 for WTPP, and Scenario 2 and 4 for WTPV was calculated. Assuming widespread participation, we calculated the potential average value of pharmaceutical collection programs in the Great Lakes region. This approximation considers a full engagement from the entire society. The total estimated value is $59.1 million per year for WTPP from Scenarios 1 and 3, and $49.71 million per year with WTPV from Scenarios 2 and 4. Although this assumption is very unlikely, the estimation provides a potential ceiling, assuming all other factors remain constant, of the monetary value of the program. This information can help program providers and policymakers make decisions in the future.

The benefit to current participants of pharmaceutical disposal programs (c) in the Great Lakes region is estimated to be $11.00 million per year from WTPP and $9.26 million per year from WTPV. However, these estimations disregard any value other members of society may associate with the program. For this reason, we consider $9.26 million per year as the floor value of these programs in the region. As awareness and participation increases, the estimated value will also increase.

From the first two assumptions, total population 18 and older and total number of households, the estimated total annual benefits in the Great Lakes are between $20.75 and $41.30 million under the WTPP estimations, and $19.70 - $39.25 million from the WTPV model. Since the sample used to estimate the mean value of the program does not provide information on how many persons per household would participate in a program, it is not possible to determine which population variable to use. However, the estimated range is a good approximation of where the total value of the program would lie and provides information for a sensitivity analysis in a cost-benefit evaluation.

4.3.4 Total Annual Benefits: Heterogeneous Population

Given that heterogeneity persists among individuals and potentially the states, an alternative circumstance where the WTP per prescription and per visit varied across states was considered. To obtain the mean willingness to pay per states, the state dummies were incorporated into the regression. The estimated values per state are reported in Table 4.16

and Table 4.17. Illinois residents are willing to pay the highest amount, unconditional mean WTP of \$0.70 and mean WTP of \$1.44 (Table 4.16). Illinois has one of the highest median income in the Mid-west. (U.S. Bureau, 2014). Higher income has been positively correlated with a positive willingness to pay. In addition, concerns for pharmaceuticals in the drinking water source and the Michigan Lake since the 2000's have led to awareness campaigns and promotion of disposal programs in collaboration with the public and private sector in Illinois. Illinois is a fairly liberal state, and a study in California found that individuals with democratic party affiliation were 13% more willing to pay for a surcharge for the creation of a medicine take-back program (Kotchen, et al., 2009). All these factors could play a role in the higher WTP when compared to the other states.

Indiana is the state with the 2nd highest mean WTPP and WTPV. The geographical proximity with Illinois, support from IISG to both Indiana and Illinois, and the high number of deaths from prescription drugs are possible explanations for this finding.

Table 4.16: Mean WTP per Prescription per State from DHM

State	WTPP E(y)	St Dev E(y)	WTPP E(y|y>0)	St Dev E(y|y>0)
Indiana	\$0.50	0.38	\$1.21	0.40
Illinois	\$0.70	0.47	\$1.44	0.49
Ohio	\$0.41	0.32	\$1.07	0.36
Michigan	\$0.48	0.35	\$1.11	0.36
Wisconsin	\$0.42	0.26	\$1.21	0.38
Minnesota	\$0.46	0.28	\$1.19	0.36

Table 4.17: Mean WTP per Visit per State from DHM

State	WTPV E(y)	St Dev E(y)	WTPV E(y|y>0)	St Dev E(y|y>0)
Indiana	$1.04	0.85	$2.39	0.85
Illinois	$1.36	0.88	$2.63	0.84
Ohio	$0.78	0.64	$2.02	0.66
Michigan	$0.93	0.73	$2.12	0.69
Wisconsin	$0.81	0.52	$2.15	0.65
Minnesota	$0.79	0.48	$2.02	0.57

To estimate the total annual benefits per state, only the total population in the region (assumptions (a)) and the number of households in the region (assumption (b)) were considered. The estimations were performed with the unconditional mean willingness to pay (WTP E(y)), and the conditional willingness to pay (WTP E(y|y>0). In these scenarios, the assumptions of number of prescriptions, number of visits, and the predicted probability for each decision stage remained the same as the homogenous case.

Scenario 5 (per prescription):

The benefits using the unconditional mean WTP across the population add up to $41.6 million assuming a WTP from all the population (a), and $20.8 million for assuming WTP per household (b) (Table 4.18). From the conditional mean WTP, benefits equal $38.5 million dollars for total population (a), and $19.3 for total number of households (b) (Table 4.18). The average from total annual benefits calculated by averaging the mean results is estimated between $20.1 million to $40.5 million for total number of households and total population, respectively.

Table 4.18: Annual Benefits per State Calculated from WTPP ($Million).

State	WTP E(y)		WTP E(y|y>0	
	(a)Total Population	(b)No. Households	(a)Total Population	(b)No. Households
Indiana	$5.1	$2.5	$4.8	$2.4
Illinois	$14.0	$6.8	$11.3	$5.4
Ohio	$7.4	$3.8	$7.5	$3.9
Michigan	$7.5	$3.7	$6.8	$3.4
Wisconsin	$3.8	$2.0	$4.2	$2.2
Minnesota	$3.9	$2.0	$3.9	$2.0
Total	$41.6	$20.8	$38.5	$19.3

Table 4.19: Annual Benefits per State Calculated from WTPV ($Million).

State	WTP E(y)		WTP E(y|y>0	
	(a)Total Population	(b)No. Households	(a)Total Population	(b)No. Households
Indiana	$5.2	$2.6	$4.8	$2.4
Illinois	$13.5	$6.5	$10.4	$5.0
Ohio	$6.9	$3.6	$7.2	$3.7
Michigan	$7.2	$3.6	$6.5	$3.2
Wisconsin	$3.6	$1.9	$3.8	$2.0
Minnesota	$3.2	$1.7	$3.3	$1.7
Total	$39.6	$19.7	$36.0	$18.0

Scenario 6:

From the WTPV, the value of pharmaceutical program estimated with the mean willingness to pay are presented in Table 4.19. The results suggest the value of society ranges from $19.7 million for total number of households to $39.6 million for total population, using the unconditional mean. With the conditional mean WTP, the benefits per year are $18.0 million for total number of households, and $36.0 million for total population. Averaging both of these estimations, the economic value of pharmaceutical programs is $18.9 million for total number of households and $37.8 for total population.

From Table 4.18 and Table 4.19, the state with the higher estimated annual benefits is Illinois, and the lowest estimated annual benefits is Minnesota. These estimates are slightly lower than the model that assumes a homogeneous sample.

4.4 Policy Implications and Conclusions

Medicine take-back programs have been implemented across the U.S. as a measure to reduce water pollution from pharmaceutical residues in the environment and reduce the risk of prescription abuse and accidental poisoning. These programs have a positive value to society associated with the environmental and public health costs avoided. However, given the data and market limitations, it is not possible to determine the societal value by quantifying the avoided costs. A contingent valuation method was used to estimate the mean annual benefits for the existence of these programs in the Great Lakes region, associating the amount individuals are willing to pay with the benefits obtained from the program.

The results suggest that the decision to pay for a medicine take-back program and the amount participants are willing to pay are influenced by different factors. Participation is influenced by the presence and number of pharmaceuticals in the household, annual income above $60,000 and age 18-45 years old. The level of consumption is influenced by the age and income level and the number of pills consumers are likely to dispose.

The estimated monetary value calculated from the DH model provides insight into consumer's preferences by approximating the societal benefits for these programs. On average, annual benefits in the Great Lakes region range between $19.5 and $39.7 million. Costs of existing programs in each state vary by the type of program, size and scope. Some of the incurred costs may include advertising, secure drop boxes, supplies, costs of consolidation of medicines at central collection site, warehousing of medicines prior to disposal, transportation to disposal facility, destruction costs and wages. The specific costs for each program vary given the type of program and the defined scope. The most economic type of medicine collection schemes are single day events. The associated costs for these events are transitory, including planning, advertising, staff, and logistics. Some of the reported total costs for these events include $6,815 plus voluntary hours of staff for a one-day event organized by the Milwaukee Metropolitan Sewerage District, to $90,000 and 1,980 hours of staff time for 59 events organized during a week in 39 locations by the Bay Area Pollution Prevention Group in California (IISG, 2009).

Permanent collection programs have continuing costs associated with the administration, transport and disposal of the medications. Reported costs of these types of programs have been reported to range from $12,000-$15,000 dollars spent annually to operate the La Crosse County disposal program of household medications (La Crosse

County, 2016), to $516,800 spent annually in King County, Washington for 1,033 pharmacy drop sites (KingCounty, 2012). Some programs have reported the incurred costs per pound or container disposed. In San Mateo County, the pharmaceutical collection program at three different police stations was estimated to cost $1.57 dollars per pound of collected medicines (Gordon, 2007). The City of Olmsted Falls, Ohio developed a medication disposal program in conjunction with a nearby hospital. To dispose of the medications, they incur in a $60 dollar fee per 28-gallon container (IISG, 2009). In Washington State, the estimated cost for a statewide program is $5.60 per pound.

Program providers and policymakers can use the estimated total benefits to perform a cost-benefit analysis when assessing the implementation of new programs. If benefits exceed the costs, the implementation of these programs should be considered as a policy measure to reduce APIs in rivers, lakes, groundwater, drinking water and other ecosystems. Comparing the total costs of implementation of a single collection program (either single day or permanent collection site) suggest a favorable cost-benefit ratio, even with a conservative estimation of the total annual benefits. Moreover, the advertising and awareness campaigns that would likely be implemented with a program, will increase participation rates, suggesting a higher mean WTP as observed in the study when the mean WTP between participants and non-participants was compared. Thus, the societal value of the programs would more likely be higher than initially estimated.

An assessment of the access to take-back medicine programs suggests a limited availability to a large percentage of the population (PSI, 2012). As the public becomes more aware about the risk of improperly disposing their medications, it is very likely the number of programs across the region will continue to grow. For more programs to be established, and a continuous support to the existing ones, stakeholders (e.g. regulators, legislators, program providers, pharmaceutical industries, tax payers) must be convinced that the societal benefits from these programs is higher than the costs sustained. This study provides insight of the willingness to pay for such programs in the region, and suggests the annual benefits are likely to surpass the costs of implementation.

4.5 List of References

Aadland, D., and A.J. Caplan. 2003. "Willingness to pay for curbside recycling with detection and mitigation of hypothetical bias." *American Journal of Agricultural Economics* 85:492-502.

Bishop, R.C., and T.A. Heberlein. 1979. "Measuring values of extramarket goods: Are indirect measures biased?" *American Journal of Agricultural Economics* 61:926-930.

Blocker, T.J., and D.L. Eckberg. 1997. "Gender and Environmentalism: Results from the 1993 General Social Survey." *Social Science Quarterly* 78:841-858.

Boardman, A.E., Greenberg, D.H, Vining, A.R and Weimer, D.L et al. 2006. "*Cost-benefit analysis: concepts and practice*." 3rd ed. Upper Saddle River, NJ

Bound, J.P., K. Kitsou, and N. Voulvoulis. 2006. "Household disposal of pharmaceuticals and perception of risk to the environment." *Environmental toxicology and pharmacology* 21:301-307.

Boyce, R.R., Brown, T.C, McClelland, G.H, Peterson, G.L and Schulze, W.D. 1992. "An experimental examination of intrinsic values as a source of the WTA-WTP disparity." *The American Economic Review* 82:1366-1373.

Burke, W.J. 2009. "Fitting and interpreting Cragg's tobit alternative using Stata." *Stata Journal* 9:584.

Camacho-Cuena, E., García-Gallego, A., Georgantzís, N. and Sabater-Grande, G. 2004. "An experimental validation of hypothetical WTP for a recyclable product." *Environmental and Resource Economics* 27:313-335.

Coombs, C.H., T.G. Bezembinder, and F. Goode. 1967. "Testing expectation theories of decision making without measuring utility or subjective probability." *Journal of Mathematical Psychology* 4:72-103.

Cragg, J.G. 1971. "Some Statistical Models for Limited Dependent Variables with Application to the Demand for Durable Goods." *Econometrica* 39:829-844.

del Saz-Salazar, S., and P. Rausell-Köster. 2008. "A double-hurdle model of urban green areas valuation: dealing with zero responses." *Landscape and urban planning* 84:241-251.

DellaVigna, S. "Psychology and economics: Evidence from the field." *National Bureau of Economic Research*.

Ferreira, S., and M. Moro. 2013. "Income and preferences for the environment: evidence from subjective well-being data." *Environment and Planning A* 45:650-667.

Glassmeyer, S.T., E.K. Hinchey, S.E. Boehme, C.G. Daughton, I.S. Ruhoy, O. Conerly, R.L. Daniels, L. Lauer, M. McCarthy, T.G. Nettesheim, K. Sykes and V.G. Thompson 2009. "Disposal practices for unwanted residential medications in the United States." *Environment International* 35:566-572.

Hammack, J., and G.M. Brown. 1974. Waterfowl and wetlands: toward bio-economic analysis: *Resources for the Future.*

Hanemann, W.M. 1999. *"The economic theory of WTP and WTA."* Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the US, EU, and Developing Countries, ed. I Bateman, KG Willis:43-93.

Hinck, J.E., Blazer, V.S., Denslow, N.D., K.R., Echols, Gale, R.W., Wieser, C., May, T.W., Ellersieck, M., Coyle, J.J. and Tillitt, D.E. 2008. "Chemical contaminants, health indicators, and reproductive biomarker responses in fish from rivers in the Southeastern United States." *Sci Total Environ* 390:538-557.

Hoffman, E., and M.L. Spitzer. 1993. "Willingness to pay vs. willingness to accept: legal and economic implications." *Wash. ULQ* 71:59.

Illinois-Indiana Sea Grant (IISG). 2009. "Unwanted Medicine Take-Back Programs: Case Studies." Available online: http://web.extension.illinois.edu/unusedmeds/disposal/ch2.cfm

Jamelske, E., and G. Kipperberg. 2006. "A contingent valuation study and benefit-cost analysis of the switch to automated collection of solid waste with single stream recycling in Madison, Wisconsin." *Public works management & policy* 11:89-103.

Kahneman, D., J.L. Knetsch, and R.H. Thaler. 1991. "Anomalies: The endowment effect, loss aversion, and status quo bias." *The journal of economic perspectives* 5:193-206.

Kahneman, D., J.L. Knetsch, and R.H. Thaler. 1990. "Experimental tests of the endowment effect and the Coase theorem." *Journal of political Economy*:1325-1348.

KingCounty. 2012. "Local Hazardous Waste Management Program in King County." Available Online: http://www.kingcounty.gov/healthservices/health/BOH/~/media/health/publichealth/documents/boh/MTB/DefiningCostsResponsibility.ashx

Knetsch, J.L. 1995. "Asymmetric valuation of gains and losses and preference order assumptions." *Economic Inquiry* 33:134-141.

Knetsch, J.L. 1990. "Environmental policy implications of disparities between willingness to pay and compensation demanded measures of values." *Journal of Environmental Economics and Management* 18:227-237.

Kotchen, M., Kallaos, J., Wheeler, K., Wong, C. and Zahller, M. 2009. "Pharmaceuticals in wastewater: Behavior, preferences, and willingness to pay for a disposal program." *Journal of Environmental Management* 90:1476-1482.

Kuspis, D., and E. Krenzelok. 1996. "What happens to expired medications? A survey of community medication disposal." *Veterinary and human toxicology* 38:48-49.

La Crosse County, 2016. *Medication Drop-off*. Solid Waste Department, Wisconsin. Available Online: http://www.co.la-crosse.wi.us/solidwaste/

Lake, I.R., I.J. Bateman, and J.P. Parfitt. 1996. "Assessing a kerbside recycling scheme: a quantitative and willingness to pay case study." *Journal of Environmental Management* 46:239-254.

Law, A.V., P. Sakharkar, A. Zargarzadeh, B.W.B. Tai, K. Hess, M. Hata, R. Mireles, C. Ha and T.J. Park. 2015. "Taking stock of medication wastage: Unused medications in US households." *Research in Social and Administrative Pharmacy* 11:571-578.

Lera-López, F., J. Faulin, and M. Sánchez. 2012. "Determinants of the willingness-to-pay for reducing the environmental impacts of road transportation." I17:215-220.

Lienhoop, N., and D. MacMillan. 2007. "Valuing wilderness in Iceland: estimation of WTA and WTP using the market stall approach to contingent valuation." *Land Use Policy* 24:289-295.

Lin, C.-H., Chuang, S.-C., Kao, D.T and Kung, C.-Y. 2006. "The role of emotions in the endowment effect." *Journal of Economic psychology* 27:589-597.

Lystlund, S., Stevens, E., Planas, L.G and Marcy, T.R. 2014. "Patient participation in a clinic-based community pharmacy medication take-back program." *Journal of the American Pharmacists Association* 54:280-284.

Martínez-Espiñeira, R. 2006. "A Box-Cox Double-Hurdle model of wildlife valuation: The citizen's perspective." *Ecological economics* 58:192-208.

Mitchell, R.C., and R.T. Carson. 1989. Using surveys to value public goods: the contingent valuation method: *Resources for the Future*.

Moon, W., et al. 2002. "Willingness to pay for environmental practices: implications for eco-labeling." *Land Economics* 78:88-102.

Musson, S.E., T. Townsend, K. Seaburg and J. Mousa. 2007. "A continuous collection system for household pharmaceutical wastes: a pilot project." *Journal of the Air & Waste Management Association* 57:828-835.

National Center for Health Statistics (NCHS). 2014 "Health, Unites States, 2013: With Special Feature on Prescription Drugs." In. Hyatsville, MD, U.S. Department of Health and Human Sciences.

Perry, L.A., B.W. Shinn, and J. Stanovich. 2014. "Quantification of ongoing community-based medication take-back program." *Journal of the American Pharmacists Association*: JAPhA 54.

Product Stewardship Institute (PSI). 2012. "Protecting our Health and the Environment: The Need for Sustainably Financed Drug Take-Back Programs." Available Online: http://c.ymcdn.com/sites/www.productstewardship.us/resource/resmgr/Resources_-_PS-Products/Pharmaceuticals_White_Paper_.pdf

Randall, A., and J.R. Stoll. 1980. "Consumer's surplus in commodity space." *The American Economic Review* 70:449-455.

Ruhoy, I.S., and C.G. Daughton. 2008. "Beyond the medicine cabinet: an analysis of where and why medications accumulate." *Environment International* 34:1157-1169.

Seehusen, D.A., and J. Edwards. 2006. "Patient practices and beliefs concerning disposal of medications." *The Journal of the American Board of Family Medicine* 19:542-547.

Thach, A.V., C.M. Brown, and N. Pope. 2013. "Consumer perceptions about a community pharmacy-based medication take back program." *Journal of Environmental Management* 127:23-27.

Tiller, K.H., P.M. Jakus, and W.M. Park. 1997. "Household willingness to pay for dropoff recycling." *Journal of Agricultural and Resource Economics*:310-320.

Tobin, J. 1958. "Estimation of relationships for limited dependent variables." *Econometrica*: journal of the Econometric Society:24-36.

Torgler, B., M.A. Garcia-Valiñas, and A. Macintyre. 2008. "Differences in preferences towards the environment: the Impact of a gender, age and parental effect." *FEEM Working Paper* No. 18.

U.S. Census Bureau. 2014. *"2010- 2014 American Community Survey 5-Year Estimates."* U.S. Department of Commerce. Available online: https://www.census.gov/

Vajda, A.M., Barber, L.B, Gray, J.L., Lopez, E.M., Woodling, J.D. and Norris, D.O. 2008. "Reproductive Disruption in Fish Downstream from an Estrogenic Wastewater Effluent." *Environ. Sci. Technol*. 42:3407-3414.

World Health Organization (WHO). 2012. *"Pharmaceuticals in drinking-water."* Water Sanitation Health. Available Online. http://www.who.int/water_sanitation_health/emerging/info_sheet_pharmaceuticals/en/

Zorić, J., and N. Hrovatin. 2012. "Household willingness to pay for green electricity in Slovenia." *Energy Policy* 47:180-187.

CHAPTER 5. OVERALL CONCLUSIONS

Pharmaceuticals residues have been found over the last couple of decades in surface and ground waters. Studies across the world have found detrimental environmental impacts of these compounds. However, due to the low concentrations of APIs found in the environmental and the limitation of reliable methods to monitor pharmaceutical residues in the environment, adverse effects in the different ecosystems are difficult to determine. Furthermore, unless species are specifically studied in a day to day basis, it is likely mild effects will go unnoticed. Studies of pharmaceutical persistence in water sources have not found a correlation between the most prescribed medications and their detection in the water supply. Thus, it is suggested prescription information is a poor proxy for medicine concentration in water. For a more accurate measure, dosage, pharmacokinetics, wastewater treatment technology and efficiency and environmental fate need to be considered. The available literature on these topics is still limited, thus, more research is needed to understand the full scope of the damage of pharmaceuticals in the environment.

Unwanted and unused pharmaceuticals also represent a public health concern. Pharmaceuticals have also been found in drinking water supply. Unfortunately, there is no information regarding the assessment of risks to human health from long term exposure to low concentrations of medicines in drinking water, or the possible combined effects from a mixture of APIs. Accumulated medications in the house also represents a problem, increasing the risk of accidental poisoning of children and pets. However, to our knowledge, no study has estimated the monetary cost of the damage of unsafe medication storage. Prescription misuse and abuse is one of the most concerning public health issues associated with pharmaceuticals. The NCHS has estimated the costs of drug abuse to the nation in $53.4 billion dollars for lost productivity, medical costs and criminal justice costs. Because of the negative consequences of improper storage and disposal of unwanted and unused pharmaceuticals, medicine collection programs have been implemented at a global, national, regional and local level to reduce the presence of APIs in the environmental and provide proper safe and secure disposal methods. Given the lack of information of the extent of the environmental damage and the public health implications, quantification of the damage avoided through these programs is difficult to assess.

Even though it is difficult to estimate the monetary cost of the improper storage and disposal of pharmaceuticals, it has been widely recognized that medicine collection programs provide and economic benefit to society. Benefits are associated with properly disposing unwanted household pharmaceuticals averting public health issues related to accidental poisoning and prescription medication abuse, reducing environmental pollution in water sources, and preventing adverse effects to organisms in the different ecosystems. Furthermore, available literature suggests that it is very difficult to establish a correlation between the medicines collected in these programs and the reduction in pollution in each location given limited market economic data. Thus, to estimate the value of disposal programs established in the Great Lakes Region, we used a non-market valuation approach. The present study, several questions related with take-back medicine programs where assessed. How likely are people to participate in pharmaceutical collection schemes? What are the factors that determine participation in the future? What are the current household practices regarding unwanted and unused medicines? What is the societal value of pharmaceutical collection programs?

Results from the first study suggest that to increase participation in these programs, there should be an increase in general environmental awareness. To increase participation in current programs, education and awareness campaigns should target younger individuals and high incomes households. Although a majority of respondents indicated they are likely to participate in such programs in the future, only a small percentage had actually done so, suggesting a potential lack of knowledge about locations of these programs.

The second study estimated mean WTP, and the annual benefits these programs provide. The benefits estimated from Scenario 1 and 3 for WTPP and Scenarios 2 and 4 for WTPV suggest that the value of pharmaceutical programs in the Great Lakes region is between \$20.75 and \$41.30 million for willingness to pay per prescription and \$19.70 - \$39.25million for willingness to pay per visit. The estimations can be used to perform a cost-benefit analyses to assess the rate of return of funds spent on these programs. A quick review of costs of single day events as well as permanent collection programs suggest a favorable cost-benefit ratio for these programs in the region. This finding indicates net social benefits of proper medicine disposal programs. From a policy perspective, we suggest a continued support for the maintenance of current programs and the implementation of more collection schemes in the region

APPENDICES

Appendix A Survey

This survey can also be retrieved from https://purdue.qualtrics.com/SE/?SID=SV_em724dM9PhaewHr

Dear Resident,

Purdue University is studying the disposal of household unwanted pharmaceuticals (expired and unused prescription and over-the-counter medicines in any form such as tablet, capsule, cream, or liquid) in the Great Lakes Area. Pharmaceuticals in the environment have negative implications for human health and ecosystems. Medicine takeback programs provide secure collection points for proper disposal of household unwanted pharmaceuticals to protect public health and the environment.

This study seeks to understand current methods of medicine disposal, and whether households are willing to participate and pay for medicine takeback programs. The results of this study will help better inform medicine takeback programs and their effectiveness in the Great Lakes area.

This survey should take no more than 10 minutes to complete. You must be at least 18 years of age to participate. Your participation in this study is voluntary and your responses to the questionnaire will be confidential. Your name is not required anywhere and all survey data will be combined to ensure anonymity.

If you have any questions, comments, or concerns, please contact: Dr. Kwamena Quagrainie (kquagrai@purdue.edu) or Sofia Vielma Delano (svielmad@purdue.edu).

1. I confirm that I'm at least 18 years of age and would like to participate in this research. *(Check one.)*
   ☐ Yes *(Go to question 2)*
   ☐ No *(End of survey)*

2. What county / state do you live in? *(Select the county and state.)*
   State __________________
   County __________________

For the purpose of this survey, unwanted pharmaceuticals are defined as expired and unused prescription and over-the-counter medicines in any form such as tablet, capsule, cream, or liquid.

3. Have you had unwanted pharmaceuticals in your home the past 24 months? *(Check one.)*
   ☐ Yes *(Go to question 3.1)*
   ☐ No *(Skip to question 4)*

3.1 Why do you have unwanted pharmaceuticals in the home? *(Check all that apply.)*

- ☐ The medication expired, and we did not know what to do with it
- ☐ Stopped taking the medication before the supply ran out
- ☐ Stopped taking the medication because of a change in medication
- ☐ Received excess medication because the pharmacy kept refilling it automatically
- ☐ The user of the medication passed away.

4. Have you ever disposed of unwanted pharmaceuticals kept in the home? (*Check one*.)

- ☐ Yes (*Go to question 5*)
- ☐ No (*Skip to question 8*)

5. How do you typically dispose of unwanted pharmaceuticals? (*Check one.*)

- ☐ Wash down the sink or flush in the toilet
- ☐ Throw in the trash
- ☐ Take to a medicine collection program
- ☐ Other *(specify)* ____

6. Typically, whose pharmaceuticals do you dispose of? (*Check all that apply.*)

- ☐ Members of my household (including yourself)
- ☐ Other relatives (non-household members)
- ☐ Non-household members (*e.g.* friends, neighbors)
- ☐ Pets

The next section asks about your participation in medicine take-back programs.
There are different ways of collecting unwanted pharmaceuticals. These include medicine take-back programs with permanent collection boxes at pharmacies, hospitals, other health care centers, or police departments; mail back programs; or periodic collection events.

7. Have you participated in any medicine take-back disposal programs? (*Check one.*)

- ☐ Yes (*Go to question 7.1*)
- ☐ No (*Go to question 8*)

7.1 Which types of take-back program have you participated in? (*Check all that apply.*)

- ☐ Take-away programs through the mail
- ☐ Single day collection events
- ☐ Permanent collection sites in pharmacies
- ☐ Permanent collection sites in hospitals or other health care centers
- ☐ Permanent collection sites in police departments
- ☐ Permanent collection sites in other centers

7.2 On average, how many different types of unwanted pharmaceuticals do you dispose of per visit? (*Write the number of types of prescriptions.*)
________________prescription types

7.3 How long have you been participating in a take-back program? (*Write the number of months.*)
______________ months

7.4 Approximately, how many miles do you travel (one-way) to your main collection point? (*Write the number of miles.*)
______________ miles

8. How likely are you to participate in a take-back program in the next 12 months? *(Check one.)*
- ☐ Very likely
- ☐ Somewhat likely
- ☐ Neither likely nor unlikely
- ☐ Somewhat unlikely
- ☐ Very unlikely

<u>The next section asks about your willingness to pay for medicine take-back programs.</u>

The presence of pharmaceuticals in surface waters is a growing environmental concern. Let's suppose local authorities are to charge a fee for take-back pharmaceutical programs at local permanent collection sites (*e.g*., pharmacies, hospitals, other health care centers, police departments, and hazardous waste centers) to address this concern.

9. How willing or unwilling are you to pay to drop off your unwanted pharmaceuticals at permanent collection locations in your county? (*Check one.*)
- ☐ Very willing
- ☐ Somewhat willing
- ☐ Neither willing nor unwilling
- ☐ Somewhat unwilling
- ☐ Very unwilling

10. On average, how many different types of unwanted pharmaceuticals are you likely to dispose of per visit? (*Write the number of types of prescriptions.*)
_________________ Prescriptions

11. How much are you willing to pay **<u>for each prescription</u>** that you drop off at a permanent collection location in your county? (*Check one)*
- ☐ $0.00
- ☐ $0.01 - $1.00
- ☐ $1.01 - $2.00
- ☐ $2.01 - $3.00
- ☐ More than $3.00

12. How much are you willing to pay **per visit** (for any number of medicines) to drop off your unwanted pharmaceuticals at a permanent collection location in your county? (*Check one)*
    - ☐ $0.00
    - ☐ $0.01 - $2.00
    - ☐ $2.01 - $4.00
    - ☐ $4.01 - $6.00
    - ☐ More than $6.00

This section asks for information that will help us learn about you.

13. How important is environmental quality to you? (*Check one.*)

☐ Extremely important
☐ Very important
☐ Neither important or unimportant
☐ Very unimportant
☐ Not at all important

14. Which of the following programs does your household engage in? (*Check all that apply.*)

☐ Recycling
☐ Composting leftover food
☐ Water conservation (*e.g*., fixing leaks, taking short showers).
☐ Energy conservation (*e.g.,* turning off lights, turning down the thermostat).
☐ Use of environmentally friendly products (*e.g*., recyclable materials)

15. What is your gender? (*Check one.*)

☐ Male
☐ Female

16. What is your age group? (*Check one.*)

☐ 18 to 25 years
☐ 26 to 35 years
☐ 36 to 45 years
☐ 46 to 55 years
☐ 56 to 65 years
☐ 65+ years

17. Which of the following best describes your ethnicity? (*Check one.*)

☐ White or Caucasian (non-Latino)
☐ African American
☐ Asian
☐ Native American
☐ Latino (White and non-White)
☐ Multi-racial
☐ Other (Specify) ____________________________________

18. What is your highest attained level of education? (*Check one.*)

☐ No formal education
☐ Elementary School
☐ High School
☐ College
☐ Graduate School
☐ Professional School (*e.g*., Law School, Medicine)

19. Which of the following categories best describes your total annual household income before taxes, from all sources? (*Check one.*)

☐ Up to $15,000
☐ $15,001 to $30,000
☐ $30,001 to $45,000
☐ $45,001 to $60,000
☐ $60,001 to $75,000
☐ $75,001 to $100,000
☐ $100,001+

20. How many years have you been living in your present county? *(Write the number of years.)*

______________ Years

21. Including yourself, how many people live in your household? *(Write the number of people.)*

_____________ People

22. How many people from the following age groups live in your household? (*Write a number for each age group.*)

_____ 0 – 5 years
_____ 6 – 25 years
_____ 26 – 60 years
_____ 60+ years

23. Do you have any of the following pets? (*Check all that apply.*)

☐ Dogs
☐ Cats
☐ Other (Specify) ____

PURDUE
UNIVERSITY

HUMAN RESEARCH PROTECTION PROGRAM
INSTITUTIONAL REVIEW BOARDS

To:	KWAMENA QUAGRAINIE KRAN 626
From:	JEANNIE DICLEMENTI, Chair Social Science IRB
Date:	04/21/2015
Committee Action:	**Exemption Granted**
IRB Action Date:	04/21/2015
IRB Protocol #:	1504015954
Study Title:	Sturdy of Unwanted Pharmaceuticals Disposal Practies

The Institutional Review Board (IRB) has reviewed the above-referenced study application and has determined that it meets the criteria for exemption under 45 CFR 46.101(b)(2) .

If you wish to make changes to this study, please refer to our guidance "**Minor Changes Not Requiring Review**" located on our website at http://www.irb.purdue.edu/policies.php. For changes requiring IRB review, please submit an **Amendment to Approved Study** form or **Personnel Amendment to Study** form, whichever is applicable, located on the forms page of our website www.irb.purdue.edu/forms.php. Please contact our office if you have any questions.

Below is a list of best practices that we request you use when conducting your research. The list contains both general items as well as those specific to the different exemption categories.

General

- To recruit from Purdue University classrooms, the instructor and all others associated with conduct of the course (e.g., teaching assistants) must not be present during announcement of the research opportunity or any recruitment activity. This may be accomplished by announcing, in advance, that class will either start later than usual or end earlier than usual so this activity may occur. It should be emphasized that attendance at the announcement and recruitment are voluntary and the student's attendance and enrollment decision will not be shared with those administering the course.
- If students earn extra credit towards their course grade through participation in a research project conducted by someone other than the course instructor(s), such as in the example above, the students participation should only be shared with the course instructor(s) at the end of the semester. Additionally, instructors who allow extra credit to be earned through participation in research must also provide an opportunity for students to earn comparable extra credit through a non-research activity requiring an amount of time and effort comparable to the research option.
- When conducting human subjects research at a non-Purdue college/university, investigators are urged to contact that institution's IRB to determine requirements for conducting research at that institution.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without

proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Category 1

- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Categories 2 and 3

- Surveys and questionnaires should indicate
  - only participants 18 years of age and over are eligible to participate in the research; and
  - that participation is voluntary; and
  - that any questions may be skipped; and
  - include the investigator's name and contact information.
- Investigators should explain to participants the amount of time required to participate. Additionally, they should explain to participants how confidentiality will be maintained or if it will not be maintained.
- When conducting focus group research, investigators cannot guarantee that all participants in the focus group will maintain the confidentiality of other group participants. The investigator should make participants aware of this potential for breach of confidentiality.
- When human subjects research will be conducted in schools or places of business, investigators must obtain written permission from an appropriate authority within the organization. If the written permission was not submitted with the study application at the time of IRB review (e.g., the school would not issue the letter without proof of IRB approval, etc.), the investigator must submit the written permission to the IRB prior to engaging in the research activities (e.g., recruitment, study procedures, etc.). This is an institutional requirement.

Category 6

- Surveys and data collection instruments should note that participation is voluntary.
- Surveys and data collection instruments should note that participants may skip any questions.
- When taste testing foods which are highly allergenic (e.g., peanuts, milk, etc.) investigators should disclose the possibility of a reaction to potential subjects.